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JAPANESE INDUSTRIAL STANDARD

Construction of Pressure Vessels

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JIS

Constructions of Pressure Vessels

B 8243-1969

1. General

1.1 Scope This standard specifies the construction practices for a steamer, evaporator, distiller, heat exchanger, autoclave, sulphurizer and other identical pressure vessels and their auxiliary equipment, expecting the followings.

- (1) Vessels to which other JIS standard is covered
- (2) Vessels to which the fire is applied
- (3) Vessels of which the maximum allowable working pressure exceeds 600 kg/cm^2
- (4) Vessels relating to the nuclear energy

Remarks

1. Air receivers, gas receivers and other identical vessels shall be complied with this standard as possible appropriately to the uses.
2. Multiplying shells for the pressure vessel shall be based on JIS B 8248 and cylindrical and tubular heat exchangers for the ordinary industrial use shall be based on JIS B 8249.
3. The maximum operating temperature of the vessel shall be the maximum allowable temperature of the material used.

1.2 Jurisdictions to be Considered as Pressure Vessels The pressure vessel shall terminate at the welded connections, flanged connections or threaded connections located nearest to the vessel and connected to the pipes for the installations out of the vessel.

1.3 Definitions of Terms The definition of the terms used in this standard shall be defined as follows.

- (1) **Pressure** Pressure above the atmospheric pressure, that is, pressure indicated in a pressure gauge (kg/cm^2)
- (2) **Maximum Working Pressure** Maximum allowable working pressure based on the strength of the vessel
- (3) **Maximum Allowable Working Pressure of the Vessel** Pressure determined for each vessel as to be operated safely at any time and not exceeded the minimum value of the maximum allowable working pressure calculated by the applicable formulas for all the portions; and it is indicated at the upper part of the vessel.
Where the vessel consists of two or more chambers and the pressures for the respective chambers are different, the maximum allowable working pressure shall be indicated for each chamber.

Remarks: When the pressure is vacuum, it shall be as to bear minus (--) pressure.

- (4) **Steel Material** It means carbon steel materials, unless otherwise designated.

Reference Standards: See P. 120 & 121.

2. Materials

2.1 Materials in General The materials used for the pressure part of a pressure vessel and its auxiliary equipment shall be those conform to the following JIS standards appropriately to the use, or those having a higher mechanical properties than the materials specified hereto. However, for the material required a special high quality or operated at a temperature below -30°C , the manufacturer shall reach an agreement upon the specification with the purchaser.

- JIS G 3101 - Rolled Steel for General Structure
- JIS G 3103 - Rolled Steel for Boilers and Other Pressure Vessels for High Temperature Service
- JIS G 3104 - Rolled Steel for Rivet
- JIS G 3106 - Rolled Steel for Welded Structure
- JIS G 3115 - Steel Plates for Pressure Vessels for Intermediate Temperature Service
- JIS G 3201 - Carbon Steel Forgings
- JIS G 3452 - Carbon Steel Pipes for Ordinary Piping
- JIS G 3454 - Carbon Steel Pipes for Pressure Service
- JIS G 3455 - Carbon Steel Pipes for High Pressure Service
- JIS G 3456 - Carbon Steel Pipes for High Temperature Service
- JIS G 3457 - Electric Arc Welded Carbon Steel Pipes
- JIS G 3458 - Alloy Steel Pipes
- JIS G 3459 - Austenitic Stainless Steel Pipes
- JIS G 3461 - Carbon Steel Boiler and Heat Exchanger Tubes
- JIS G 3462 - Alloy Steel Boiler and Heat Exchanger Tubes
- JIS G 3463 - Stainless Steel Boiler and Heat Exchanger Tubes
- JIS G 4051 - Carbon Steel for Machine Structural Use
- JIS G 4102 - Nickel Chromium Steels
- JIS G 4103 - Nickel Chromium Molybdenum Steels
- JIS G 4104 - Chromium Steels
- JIS G 4105 - Chromium Molybdenum Steels
- JIS G 4202 - Aluminium Chromium Molybdenum Steels
- JIS G 4303 - Stainless Steel Bars
- JIS G 4304 - Hot Rolled Stainless Steel Sheet and Plate
- JIS G 4305 - Cold Rolled Stainless Steel Sheet and Plate
- JIS G 5101 - Carbon Steel Castings
- JIS G 5111 - Alloy Steel Castings for Structural Purposes
- JIS G 5121 - Stainless Steel Castings
- JIS G 5501 - Grey Iron Castings
- JIS G 5502 - Spheroidal Graphite Iron Castings
- JIS G 5702 - Black Heart Malleable Iron Castings
- JIS G 5703 - White Heart Malleable Iron Castings
- JIS G 5704 - Pearlitic Malleable Iron Castings
- JIS H 3101 - Copper Sheet and Plate
- JIS H 3104 - Deoxidized Copper Sheet and Plate
- JIS H 3201 - Brass Sheet and Plate
- JIS H 3202 - Leaded Brass Sheet and Plate
- JIS H 3203 - Naval Brass Sheet and Plate
- JIS H 3208 - Special Aluminium Bronze Sheet and Plate
- JIS H 3601 - Seamless Copper Pipe and Tube
- JIS H 3603 - Deoxidized Copper Pipe and Tube
- JIS H 3631 - Seamless Brass Pipe and Tube
- JIS H 3632 - Seamless Copper Alloy Condenser Tube
- JIS H 3651 - Silicon Bronze Pipe and Tube
- JIS H 3661 - Seamless Nickel-Copper Alloy Pipe and Tube
- JIS H 4101 - Aluminium Sheet, Plate and Circle

JIS H 4104 - Anti-Corrosion Aluminium Alloy Sheet and Plate (Rectangle)
 JIS H 4131 - Forgings of Aluminium Alloy
 JIS H 4141 - Aluminium Seamless Tube
 JIS H 4142 - Aluminium Welded Tube
 JIS H 4143 - Anti-Corrosion Aluminium Alloy Seamless Tube
 JIS H 4163 - Anti-Corrosion Aluminium Rod and Bar
 JIS H 4172 - Anti-Corrosion Aluminium Alloy Extruded Shape
 JIS H 4311 - Lead Pipes
 JIS H 4312 - Lead Pipes for Water Supply
 JIS H 4313 - Hard Lead Pipes
 JIS H 4600 - Titanium Plates
 JIS H 4630 - Titanium Pipes for Ordinary Piping
 JIS H 4631 - Titanium Tubing for Heat Exchanger
 JIS H 4650 - Titanium Bars
 JIS H 5102 - High Strength Brass Castings
 JIS H 5111 - Bronze Castings
 JIS H 5112 - Silzin Bronze Castings
 JIS H 5113 - Phosphor Bronze Castings
 JIS H 5114 - Aluminium Bronze Castings
 JIS H 5202 - Aluminium Alloy Castings

2.2 Restrictions in Uses of Carbon Steels The carbon steel used for a shell, head or other similar part of the following pressure vessels shall be one of the plates conformed to JIS G 3103 - Rolled Steel for Boilers and Other Pressure Vessels for High Temperature Service, (hereinafter named as steel plate for boilers), JIS G 3106 - Rolled Steel for Welded Structure, (hereinafter named as steel plate for welded structure) or the plates having higher mechanical qualities than the above.

- (a) Pressure vessels of which the maximum allowable working pressure is over 16 kg/cm^2
- (b) Pressure vessels of which the maximum allowable operating temperature is over 350°C (except JIS G 3106 - Rolled Steel for Welded Structure)
- (c) Pressure vessels which contains lethal substances⁽¹⁾
- (d) Pressure vessels of which the maximum allowable working pressure is over 10 kg/cm^2 and the longitudinal joint is welded.

Note⁽¹⁾ Lethal substances are meant poisonous gases or liquids of such a nature that a very small amount of the gas or of the vapor of the liquid (mixed or unmixed with air) is dangerous to life when inhaled. Some such substances are hydrocyanic acid, carbonyl chloride, cyanogen, mustard gas, xylol bromide and, etc. Chlorine, ammonia, natural and manufactured gas, liquefied petroleum (such as propane, butane, butadiene) and vapors of any other petroleum products are not classified as lethal substances.

2.3 Omissions of Tests In the following cases, the stipulated tests for the material may be omitted, unless the purchaser is specially designated.

- (1) Materials used for a vessel not exceeding 10 kg/cm^2 in maximum allowable working pressure and not exceeding 200°C in maximum operating temperature, provided that the materials shall be checked upon the complete durability for the use by performing a bending test or other equivalent tests.

- (2) Materials used for a portion exerting comparatively small effect upon the safety of the vessel and of which the tests are not practical.

2.4 Dimensional Tolerances of Principal Materials Though the actual thickness of the materials other than piping is less than the required thickness in computations, the followings may be used.

- (1) Steel plates for boilers of which the difference between the actual thickness and the required thickness is within the allowable tolerance specified in JIS standard.
- (2) Steel plates other than the steel plate for boiler of which the difference between the actual thickness and the required thickness does not exceed 0.25 mm.

2.5 Tensile Strength of Steels to be Used in Computations The tensile strength of a steel to be used in computations shall be as follows.

- (1) The tensile strength of a steel to be used in computations shall be the minimum value of the tensile strength specified in JIS standard appropriately to the kind of the steel (when one kind of the steel is used for single purpose and all of the tensile strengths thereof are greater than the minimum value specified in JIS standard for the material thereof, it may be the minimum tensile strength of the steels used.) However, it need not be less than 36 kg/mm^2 , except steel pipes.
- (2) The tensile strength of a carbon steel to be used in computations for which the tests specified in JIS standard are omitted, shall be as follows.
 - (a) Where the steel for which the tests specified in JIS standard are omitted and to which the tensile test is performed afterward, it shall be the minimum tensile strength found by this test (it shall be 39 kg/mm^2 , even if it exceeds 39 kg/mm^2). However, it need not be less than 36 kg/mm^2 .
 - (b) Where the steel listed in 2.1 (except steel pipes) is not cleared for the tensile strength, it shall be 36 kg/mm^2 .
- (3) The tensile strength to be used in computations for a material not specified in JIS standard shall be properly established basing on the chemical compositions and the mechanical properties of the material.

Remarks: The tensile strength to be used in computations for a material of which the mechanical properties are not specified in JIS standard, shall be properly established basing on the chemical compositions and the heat treatment of the material.

2.6 Allowable Stress Values to be Used in Computations for Steels Operated at High Temperatures The allowable stress value to be used in computations for a steel operated at a high temperature shall be in accordance with Figs. 2.1, 2.2, 2.3 and Table 2.1. However, the values in the brackets shall not be used, unless specially recognized by inspection authorities.

Fig. 2.1. Allowable Tensile Stress Value for Carbon Steel Plates

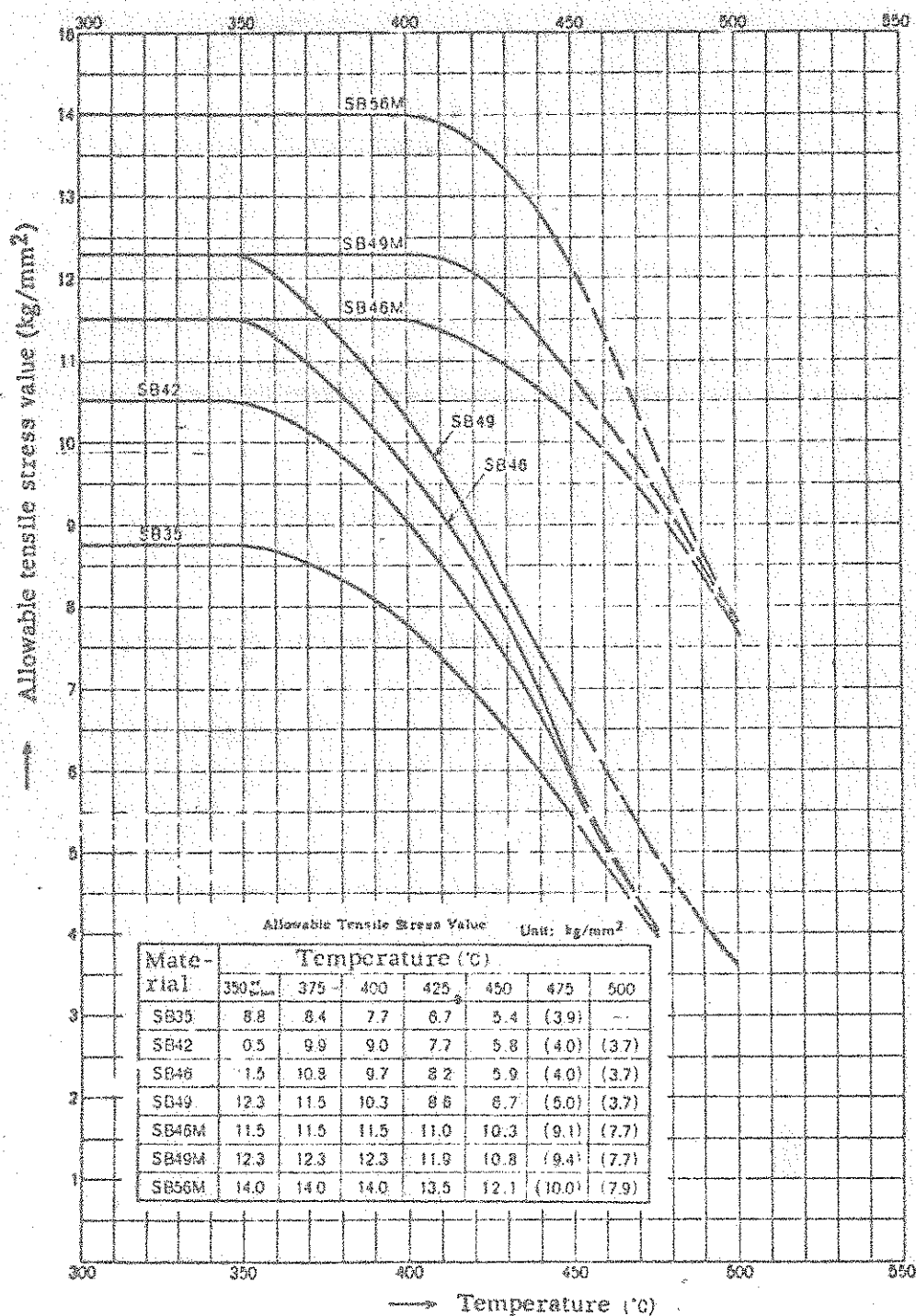


Fig. 2.2. Allowable Tensile Stress Values for Carbon Steel Tubes

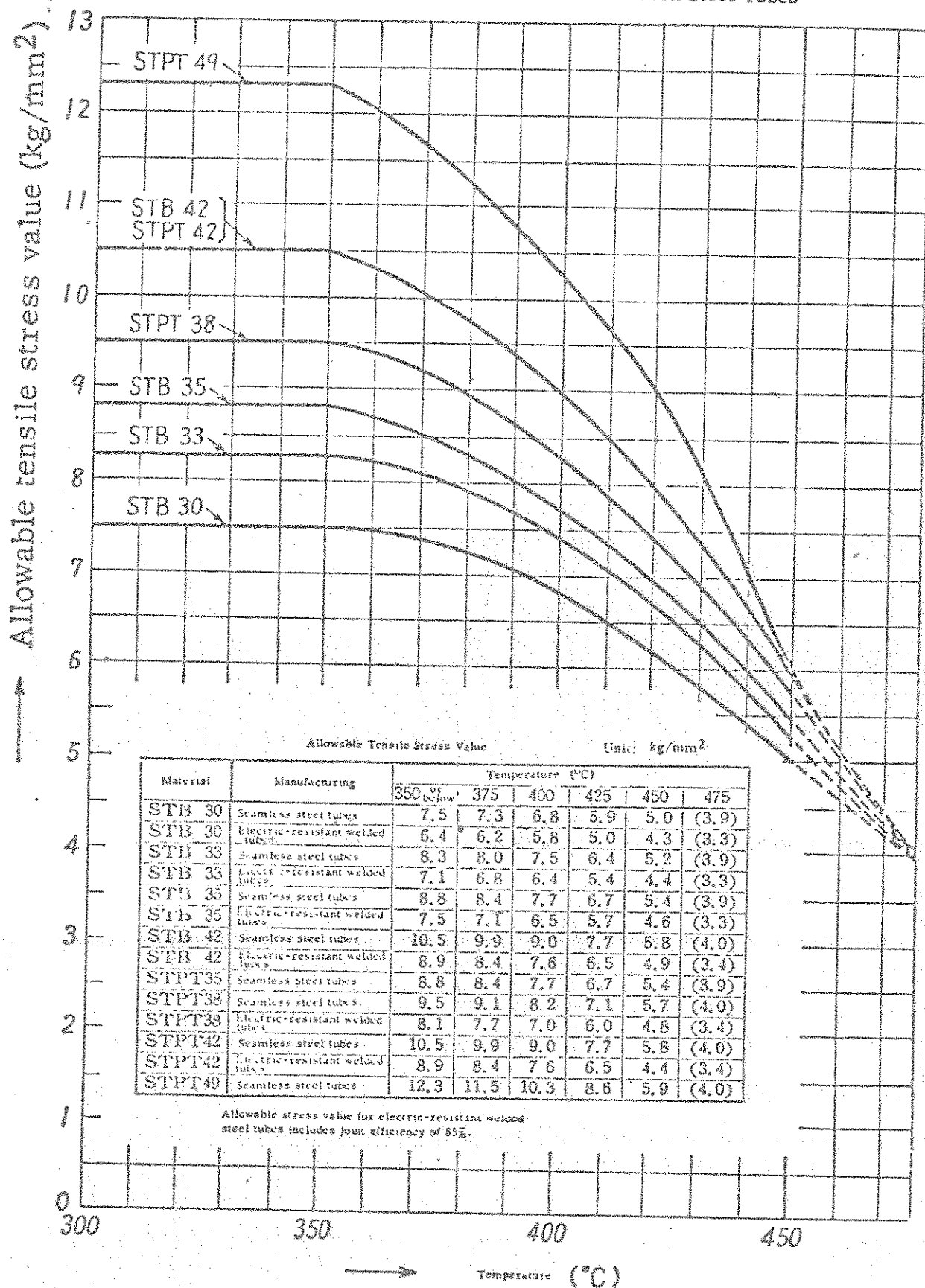
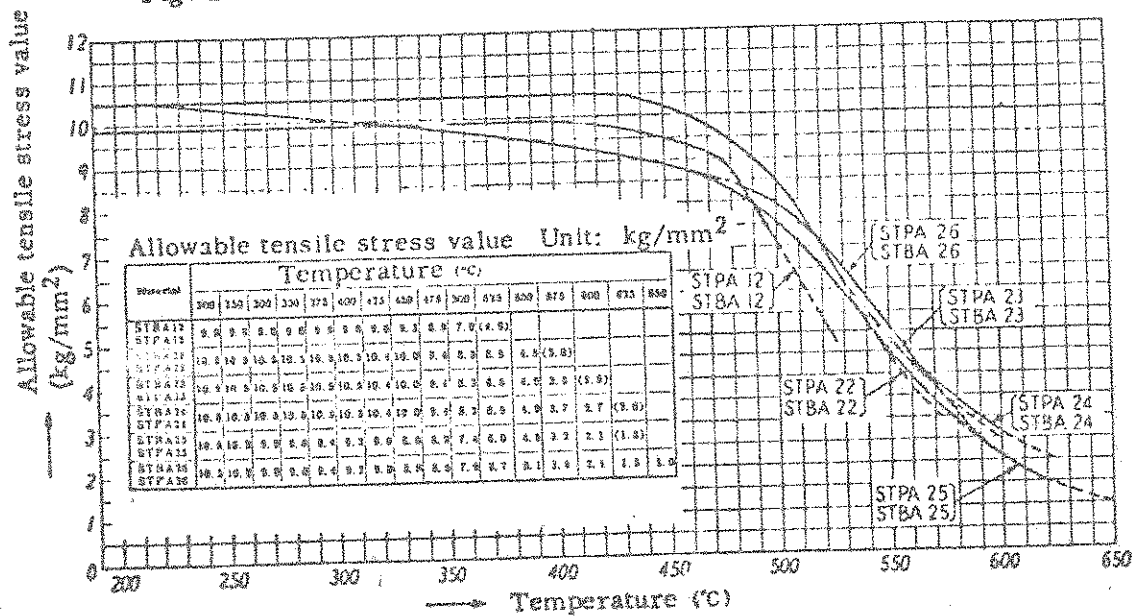


Fig. 2.3. Allowable Tensile Stress Value for Special Steel Tubes



Unit: kg/mm²

Table 2.1. Allowable Tensile Stress Values for Stainless Steels

Specifi- cation	Class	Nota- tion	Nominal composition %	Min. tensile strength kg/mm ²	Temperature (°C)																														
					-30	-20	-10	0	10	20	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800	
Stainless steel boiler and heat exchang- er tubes	51	SUS 31 TB	13 Cr-low C	42	10.5	10.2	10.0	9.7	9.4	9.2	9.1	8.9	8.8	8.7	8.6	8.4	8.2	7.8	7.4	6.9	6.2	5.1	3.9	2.7	1.8	1.2									
	24	SUS 24 TB	18 Cr	42	10.5	10.2	10.0	9.7	9.4	9.2	9.1	8.9	8.8	8.7	8.6	8.4	8.2	7.8	7.4	6.9	6.3	5.2	4.0	2.9	2.1	1.6									
	27	SUS 27 TB	18 Cr-8 Ni	52	13.0	11.9	11.1	9.6	8.7	8.4	8.1	7.9	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.1	6.9	6.7	6.5	6.1	5.6	4.7	3.2	3.1	2.5	2.0	1.6	1.3	1.0		
	27H	SUS 27H TB	18 Cr-8 Ni	52	13.0	11.9	11.1	9.6	8.7	8.4	8.1	7.9	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.1	6.9	6.7	6.5	6.1	5.6	4.7	3.2	3.1	2.5	2.0	1.6	1.3	1.0		
	28	SUS 28 TB	18 Cr-10 Ni- very low C	49	12.3	11.3	10.6	9.2	7.9	7.4	7.0	6.7	6.5	6.3	6.1	6.0	5.8	5.7																	
	29	SUS 29 TB	18 Cr-10 Ni-Ti	52	13.0	12.1	11.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.6	8.4	8.4	8.2	8.0	7.9	7.8	7.6	7.1	5.9	4.1	3.1	2.4	1.7	1.2	0.9	0.7	0.6			
	29H	SUS 29H TB	18 Cr-10 Ni-Ti	52	13.0	12.1	11.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.6	8.4	8.4	8.2	8.0	7.9	7.8	7.7	7.4	6.6	5.2	3.8	2.9	2.2	1.7	1.3	0.9	0.7			
	32	SUS 32 TB	18 Cr-12 Ni-2 Mo	52	13.0	11.9	11.1	9.6	9.3	9.0	8.7	8.5	8.3	8.1	7.9	7.7	7.6	7.5	7.3	7.2	7.0	6.8	6.7	6.5	5.9	4.8	3.8	3.0	2.1	1.6	1.2	0.9			
	32H	SUS 32H TB	18 Cr-12 Ni-2 Mo	52	13.0	12.2	11.9	11.5	11.1	10.9	10.7	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	
	33	SUS 33 TB	18 Cr-12 Ni-2 Mo -very low C	49	12.3	11.7	11.3	10.2	8.6	8.2	7.4	7.6	7.3	7.1	6.8	6.6	6.4	6.2	6.0																
41	SUS 41 TB	22 Cr-12 Ni	52	13.0	12.3	11.8	11.0	10.5	10.3	10.0	9.8	9.5	9.3	9.1	8.9	8.8	8.6	8.4	8.2	8.0	7.5	6.6	5.5	4.3	3.4	2.6	2.1	1.7	1.3	1.0	0.8	0.6			
42	SUS 42 TB	25 Cr-20 Ni	52	13.0	12.5	12.0	11.1	10.2	9.9	9.6	9.3	9.1	8.9	8.8	8.6	8.4	8.2	8.0	7.9	7.8	7.6	7.1	5.9	4.1	3.1	2.4	1.7	1.2	0.9	0.7	0.6				
43	SUS 43 TB	18 Cr-10 Ni-Nb	52	13.0	12.1	11.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.6	8.4	8.4	8.2	8.0	7.9	7.8	7.6	7.1	5.9	4.1	3.1	2.4	1.7	1.2	0.9	0.7	0.6				
43H	SUS 43H TB	18 Cr-10 Ni-Nb	52	13.0	12.3	11.7	11.1	10.9	10.7	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6		
27	SUS 27 TP	10 Cr-8 Ni	52	13.0	11.9	11.1	9.6	8.7	8.4	8.1	7.9	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.1	6.9	6.7	6.5	6.1	5.6	4.7	3.8	3.1	2.5	2.0	1.6	1.3	1.0			

Stainless
steel
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Tab. 2.1

27H	SUS 27H TP	18Cr-8Ni	52
28	SUS 28 TP	18Cr-10Ni very low C	49
29	SUS 29 TP	18Cr-10Ni-Ti	52
29H	SUS 29H TP	18Cr-10Ni-Ti	52
32	SUS 32 TP	18Cr-12Ni-2Mo	52
32H	SUS 32H TP	18Cr-12Ni-2Mo	52
33	SUS 33 TP	18Cr-12Ni-2Mo very low C	49
41.	SUS 41 TP	22Cr-12Ni	52
42	SUS 42 TP	25Cr-20Ni	52
43	SUS 43 TP	16Cr-16Ni-Nb	52
43H	SUS 43H TP	18Cr-10Ni-Nb	52

1. The stainless steel pipes listed in this Table shall wholly be of seamless.
2. The value for an intermediate temperature shall be determined by the interpolation.
3. The values in the upper two rows for SUS 42 TB and SUS 42 TP may be applied when the austenitic crystal grains of the material (refer to JIS G 0531) is No. 6 or coarser.
4. As the grainity of SUS 24 TB in normal temperatures will be increased after operating at a temperature exceeding 425° C, so it shall not be used at the temperature above, unless the cases of a specially necessary.
5. The values in 550° C or more for SUS 27 TP, 32 TB, 41 TB, 42 TB, SUS 27 TP, 32 TP, 41 TP and 42 TP shall apply to the materials containing 0.04 % or more of carbon. However, as the values in 550° C or more are listed for the information, so they are out of the application of this specification.
6. The allowable stress values listed in the lower row (2nd and 4th rows for SUS 42 TB and SUS 42 TP) of this Table shall not be used for the portions such as a flange with a gasket in which some leakage or other functional disorders may occur as the results of distortions.
7. Where the steels listed in this Table are manufactured by automatic arc welding without adding metal and are performed solution heat treatments, after cold working, to get a perfect corrosion resistant of the base metal and the welded parts, the allowable stress values listed in this Table may be used, excepting SUS 31 TB and SUS 24 TB.

2.7 Compressive Strength Values of Steels to be Used in Computations The compressive strength value of a steel to be used in computations shall be equal to the tensile strength.

2.8 Shearing Strength Values of Steels to be Used in Computations The shearing strength value of a steel to be used in computations shall be 85 % of the tensile strength.

2.9 Tensile Strength Values of Clad Steels The tensile strength value of a clad steel shall be determined by the following formula. However, a proper corrosion allowance shall be added, when the corrossions are expected, but the allowances thereof shall not be added to t_1 or t_2 in the following formula.

$$\sigma = \frac{\sigma_1 t_1 + \sigma_2 t_2}{t_1 + t_2}$$

where, σ : tensile strength of the clad steel (kg/mm²)
 σ_1 : tensile strength of the base metal (kg/mm²)
 σ_2 : tensile strength of the clad metal (kg/mm²)
 t_1 : thickness of the base metal (mm)
 t_2 : thickness of the clad metal (mm)

Remarks: The above formula shall be used only when the clad metal is integrally joined to the base metal and the butt joint of the clad steel is completely welded by depositing corrosion-resisting weld metals. When these conditions are not satisfied, only the thickness of the base metal shall be used in the computations.

2.10 Restrictions in Uses of Cast Iron Cast iron shall not be used in the follows.

- (1) Vessels which generate a flammable or poisonous gas
- (2) For gray cast iron, vessels which contain gas or liquid exceeding 250° C in temperature or which are subjected to the pressure exceeding 11 kg/cm² (16 kg/cm² for the fitting).
- (3) For black-heart malleable cast iron, and special high-tension cast iron adding other elements, vessels which contain gas or liquid exceeding 350° C in temperature or which are subjected to the pressure exceeding 18 kg/cm² (24 kg/cm² for the fitting).

2.11 Tensile Strength Values of Cast Iron to be Used in Computations The tensile strength value of a cast iron to be used in computations shall be as follows.

- (1) Minimum values of the tensile strength specified in IIS standard for the appropriate cast iron.
- (2) 10 kg/mm² (28 kg/mm² for black-heart malleable cast iron), if the tensile strength is not available.

2.12 Allowable Stress Values of Cast Iron to be Used in Computations The allowable stress value of a cast iron to be used in computations shall be as follows.

- (1) The allowable tensile stress value of a cast iron shall be 1/8 of the tensile strength.
- (2) The allowable compressive stress value of a cast iron shall be twice the allowable tensile stress value.
- (3) The allowable bending stress value of a cast iron shall be 1.5 times the allowable tensile stress value.
- (4) The allowable tensile stress value of a black-heart malleable cast iron shall be 1/6 of the tensile strength.

2.13 Allowable Tensile Stress Values of Steel Casting The allowable tensile stress value of a steel casting shall be as follows.

- (1) The allowable tensile stress value of a carbon steel casting shall be $1/6$ of the tensile strength.
- (2) Where the chemical compositions in Table 2.2 are designated when manufacturing, the ratio shall be $1/5$.

Table 2.2. Designated Chemical Compositions

Composition % Kind	C	Mn	P	S	Si
SC 37 SC 42	0.25 or under	0.70 or under	0.05 or under	0.05 or under	0.60 or under
SC 46 SC 49	0.35 or under	0.70 or under	0.05 or under	0.05 or under	0.60 or under

Remarks: 1. Mn content may be increased by 0.04 % above the maximum value in the Table, at each decrease of 0.01 % of C content, provided that Mn content shall not exceed 1.10 %.

2. Ni, Cr and Cu contained as impurities are limited to not exceed 0.5 % for each and 1.0 % for total.

- (3) Where there is no injurious defect after performing the following inspections by the manufacturer in addition to (2), the ratio of the allowable tensile stress value to the tensile strength may be $1/4.5$.

(a) All the surfaces of the steel casting (including the finished surfaces) shall be completely examined.

(b) Where more than 5 castings are being produced at least 3 samples among 5 first castings and 1 sample among 5 or fractions of the additional castings shall be examined by cutting or radiographing the portions in which defects are expected.

(c) The casting not subjected to the inspection in (b) shall be examined the portions in which defects are expected by any one of the following methods.

Magnetic particle test Fluorescent fluid penetrant test
Dye penetrant test Oil penetrant test Corrosion test

- (4) Where only one casting is being produced, the ratio of the allowable tensile stress value to the tensile strength may be $1/4.5$, when there is no injurious defect after performing surface inspections by the manufacturer in addition to (2) and radiographing for all the portions in which defects are expected.

- (5) The allowable tensile stress value for a steel casting other than the carbon steel casting shall be $1/6$ of the tensile strength.

2.14 Allowable Stress Values of Electric-Resistance Weld Tubes and Forge-Weld Tubes

The allowable stress value of an electric-resistance weld tube and a forge-weld tube shall be 85 % and 65 % of the seamless tube respectively.

2.15 Restrictions in Uses of Carbon Steel Pipes for Ordinary Piping The carbon steel pipe for ordinary piping shall not be used for a pressure vessel exceeding 10 kg/cm^2 in maximum allowable working pressure.

2.16 Restrictions in Uses of Copper and Copper Alloy The restriction in an use of copper and copper alloy shall be as follows.

- (1) Copper shall not be used for the portions which contain gas or liquid exceeding 205° C in temperature (except the connection to pressure gauge, fluid level gauge, lining and gasket).
- (2) Copper alloy specified in JIS H 5111 - Bronze Castings, Class 3, shall not be used for the portions which contain gas or liquid exceeding 235° C in temperature.
- (3) Copper alloy other than that specified in JIS H 5111 - Bronze Castings, Class 3, shall not be used for the portions which contain gas or liquid exceeding 205° C in temperature.

2.17 Allowable Tensile Stress Values of Copper and Copper Alloy to be Used in Computations
The allowable tensile stress value of a copper and copper alloy to be used in computations shall be as shown in Fig. 2.4, 2.5 and 2.6.

2.18 Restrictions in Uses of Aluminium and Aluminium Alloy Aluminium and aluminium alloy shall not be used for the portions which contain gas or liquid exceeding 205° C in temperature (except the connection to pressure gauge, fluid level gauge, lining and gasket).

2.19 Allowable Tensile Stress Values of Aluminium and Aluminium Alloy to be Used in Computations The allowable tensile stress value of an aluminium and aluminium alloy to be used in computations shall be as shown in Figs. 2.7, 2.8 and 2.9.



Fig. 2.4. Allowable Tensile Stress Values for Copper Sheets and Copper-Alloy Sheets (Annealed Values)

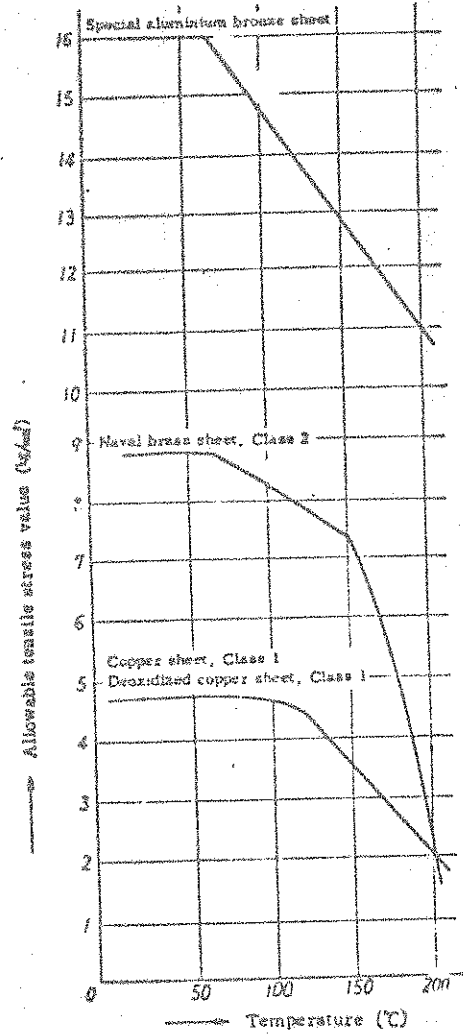


Fig. 2.5. Allowable Tensile Stress Values for Copper Tubes and Copper-Alloy Tubes (Annealed Values)

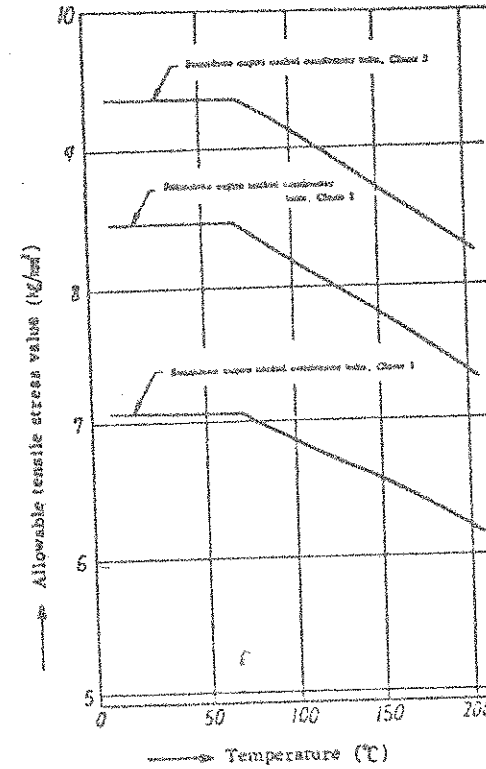
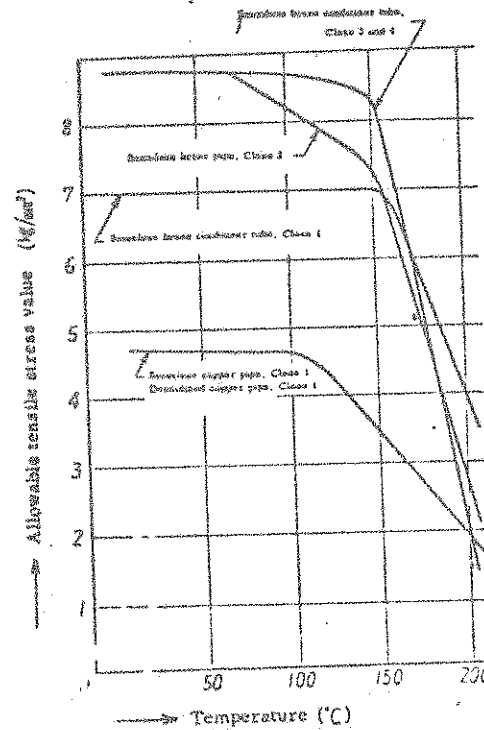




Fig. 2.6. Allowable Tensile Stress Values for Bronze Casting

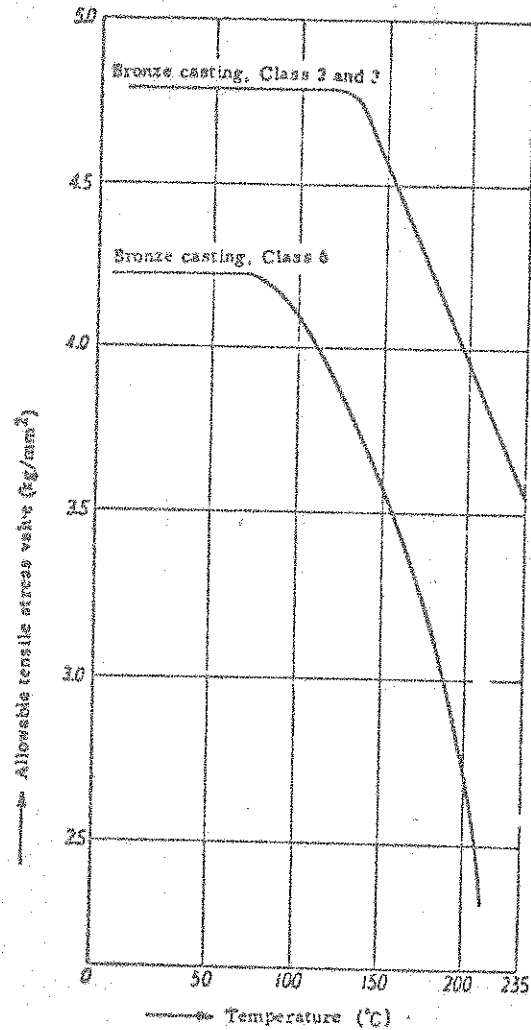


Fig. 2.7. Allowable Tensile Stress Values for Aluminium Plates

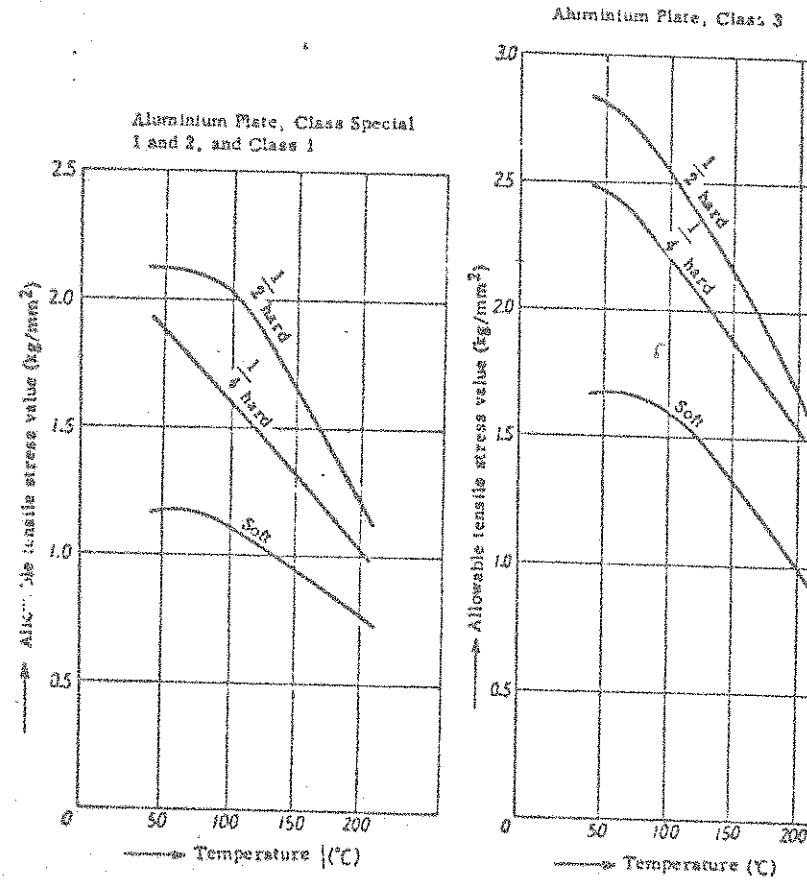




Fig. 2.8. Allowable Tensile Stress Values
for Anti-corrosion Aluminium Alloy Plates

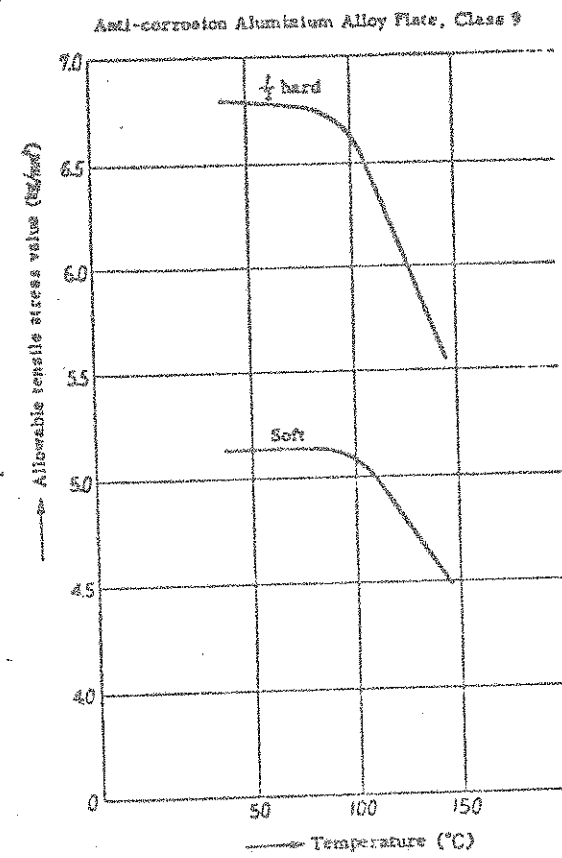
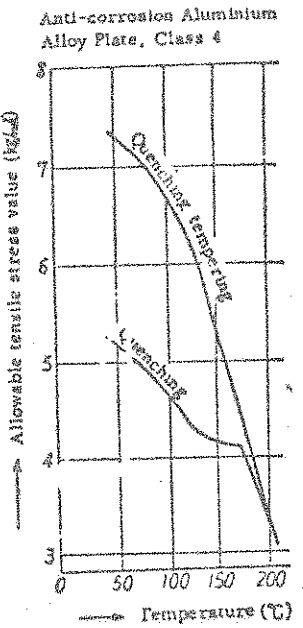
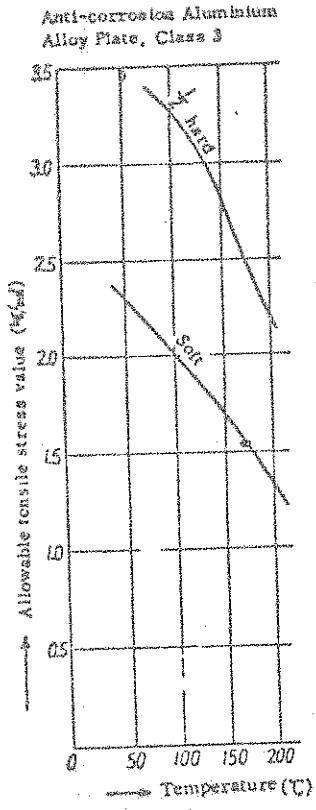
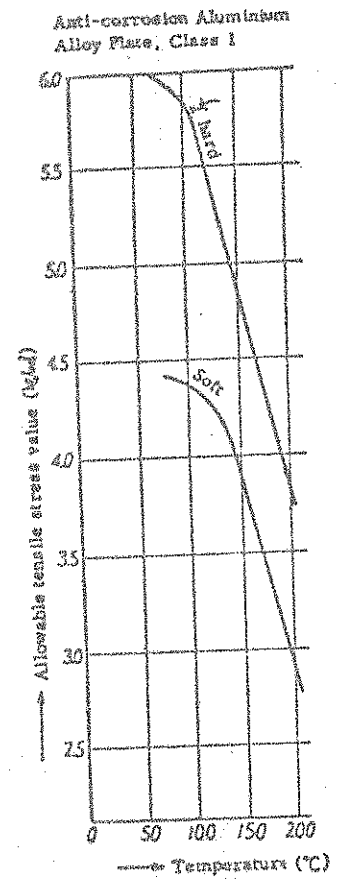
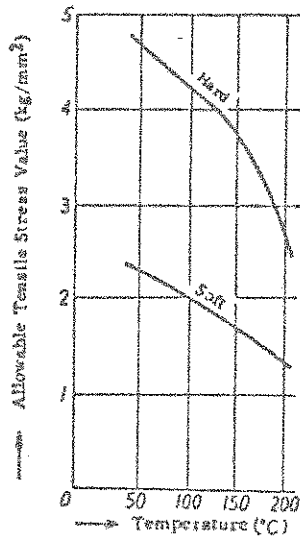
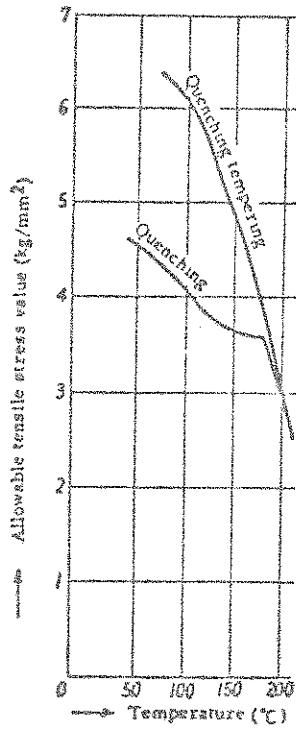


Fig. 2.9. Allowable Tensile Stress Values for Anti-corrosion Aluminium Alloy Seamless Tubes

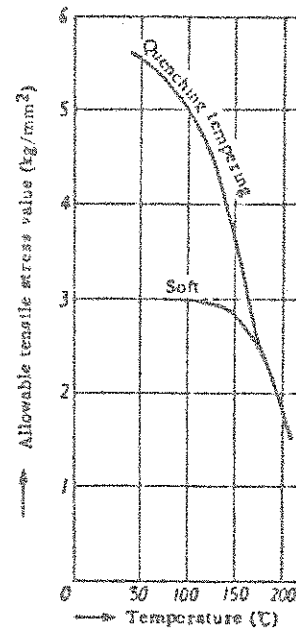
Anti-corrosion Aluminium Alloy Seamless Tube, Class 3



Anti-corrosion Aluminium Alloy Seamless Tube, Class 4

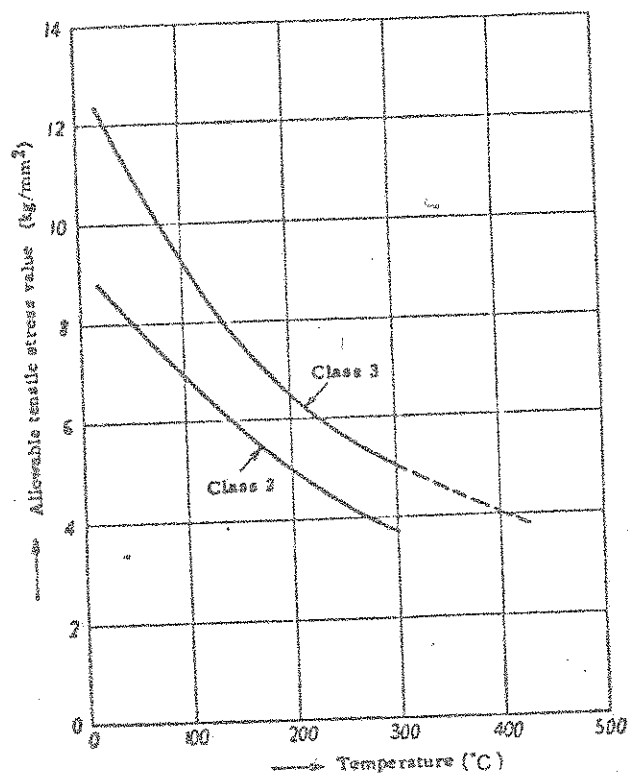


Anti-corrosion Aluminium Alloy Seamless Tubes, Class 5



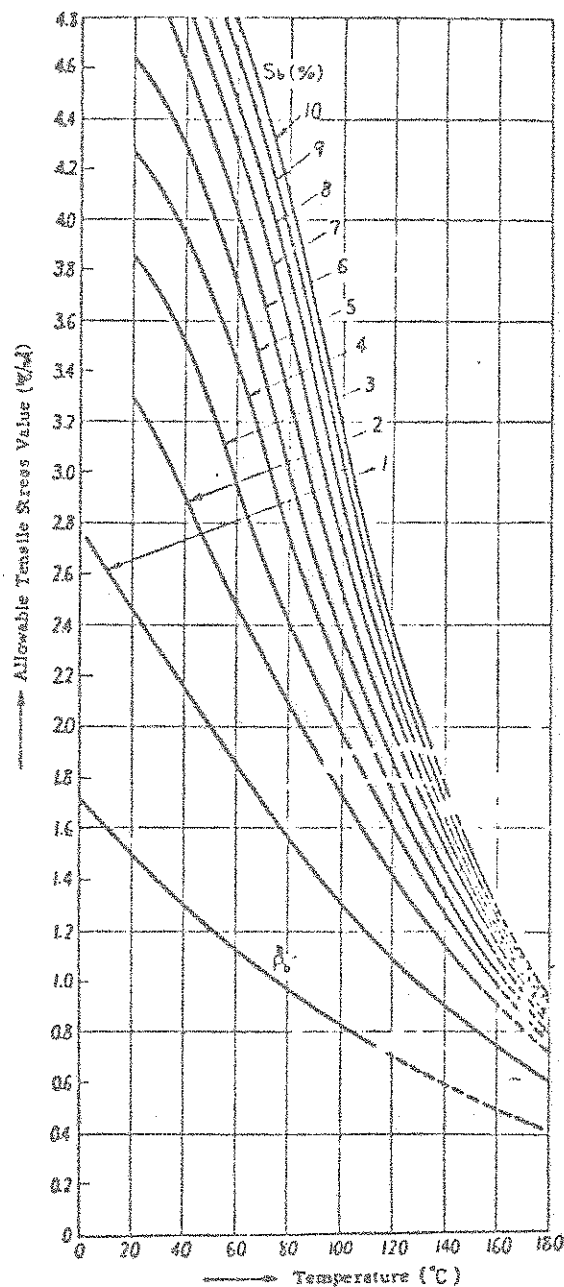
2.20 Allowable Tensile Stress Values of Titanium to be Used in Computations The allowable tensile stress value of a titanium to be used in computations shall be as shown in Fig. 2.10.

Fig. 2.10. Allowable Tensile Stress Value for Titanium



2.21 Allowable Tensile Stress Values of Lead Pipes and Hard Lead Pipes to be Used in Computations The allowable tensile stress value of a lead pipe and hard lead pipe to be used in computations shall be as shown in Fig. 2.11.

Fig. 2.11. Allowable Tensile Stress Values
for Lead Pipes and Hard Lead Pipes



3. Construction in General

3.1 General The vessels and their auxiliaries shall have an adequate strength and shall be safe against the partial stresses caused by the supports or to the heat effects in the operating conditions; and moreover, they shall bear the loads on them, when so constructed.

And, the external forces due to wind pressures, earthquakes, vibrations, etc. shall be, if necessary, taken into consideration.

3.2 Maximum Operating Temperatures The maximum operating temperature used in the design of the vessels shall be based on the highest temperature expected under operating conditions for the part considered. The temperature used in the design of a plate shall be based on the temperature at the centre of the plate thickness.

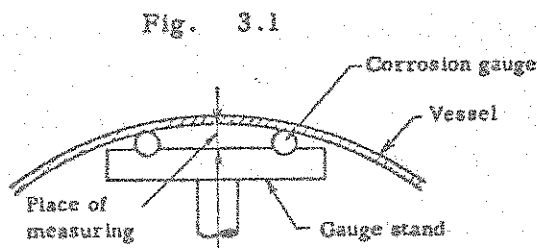
3.3 Maximum Working Pressures to be Used in Computations The highest working pressure expected under operating conditions for the part considered shall be taken as the maximum working pressure to be used in the computations for the part thereof (the pressure may be different, even one vessel, to the constructions of the vessel, the operating conditions, the operating temperatures, etc.).

3.4 Corrosion Allowances, Abrasion Allowances or Other Allowances for Damaging The part of a vessel which is subjected to corroding, abrading or other damaging, shall be provided with corrosion allowances, abrasion allowances or allowances for damaging (hereinafter, generically named as corrosion allowance) over the required thickness determined by the formula.

The parts which are difficult to establish the rate of corrosions or other damagings, shall be so constructed that the parts thereof can be easily inspected.

3.5 Telltale holes, etc. The part to which the corrosion allowance is added, may provide with telltale holes to catch the heaviness of corrosions or corrosion gauges⁽²⁾ to observe the progress of corrosions. The telltale hole shall be drilled at least 5 mm in diameter and to a depth not less than 80 % of the thickness required for a seamless shell of the like dimensions, and shall be drilled into the surface opposite to that where the heaviest corrosion is expected. If linings are used, the telltale hole may be drilled to the thickness of the lining.

Note (2) The corrosion gauge shall be of the corrosion-resistant material relating to the content. Example of a corrosion gauge is shown in Fig. 3.1.



3.6 Strength of Linings When linings are used to prevent corrosions, the strength of the linings shall not be added to the strength of the vessel.

4. Joints

4.1 Arrangement of Rivets The rivet (steel rivet hereinafter, unless otherwise specified) in a joint shall be so arranged as to uniform the stress in the plate and to get the tight joint. The rivet other than the steel rivet shall be similarly arranged.

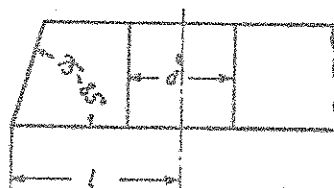
4.2 Restrictions for Longitudinal joints The restriction for a longitudinal joint shall be as follows.

- (1) The riveted longitudinal joint of a shell which exceeds 1000 mm in inside diameter and 10 kg/cm² in maximum allowable working pressure, or 1000 mm in inside diameter and 230° C in maximum operating temperature, shall not be of lap construction. However, the riveted longitudinal joints of the following shells need not be applied to.
 - (a) Shells of which the plate thickness is not less than 1.8 times the required thickness.
 - (b) Double shells of which both inner and outer plates are attached by staybolts.
- (2) The riveted longitudinal joint of a shell shall not be of single-strap butt type construction. However, the riveted longitudinal joint of a shell, to be applied inside lining, which does not exceed 10 kg/cm² in maximum allowable working pressure and 230° C in maximum operating temperature, need not be applied to.
- (3) When the riveted longitudinal joint of a shell is of single-strap butt construction, the strap shall be provided with telltale holes.

4.3 Allowable Shearing Stress Values in Rivets The allowable shearing stress value of a rivet shall be 85 % of the allowable tensile stress value. However, it shall be 7 kg/mm² for the rivet material of which the tensile stress value is unknown.

4.4 Calking Faces The face to be calked shall be beveled to an angle 75 to 85° before calking, as shown in Fig. 4.1.

Fig. 4.1



4.5 Minimum Thickness of Buttstraps The minimum required thickness of a buttstrap shall be as follows.

- (1) The minimum required thickness of a buttstrap for a double-strap joint shall be determined by the following formula.

$$t_b = 0.6t + 2$$

where, t_b : minimum required thickness of the buttstrap (mm);
when a corrosion allowance is added to the shell plate,
the same amount of the allowance shall be added to the inner
buttstrap.

t : required thickness of the shell plate (mm)

- (2) The minimum required thickness of a buttstrap for a single-strap joint shall be twice the required thickness of the buttstrap for the double-strap joint. However, the minimum required thickness of a buttstrap for a single-strap circumferential joint may be equal to the actual thickness of the shell plate.

4.6 Transverse Pitches of Rows of Rivets The transverse pitch of the rows of rivets shall be determined by the following formulas (See Fig. 4.2).

- (1) For longitudinal joints

$$\text{If } \frac{p}{d} \text{ is 4 or less } S \geq 2d$$

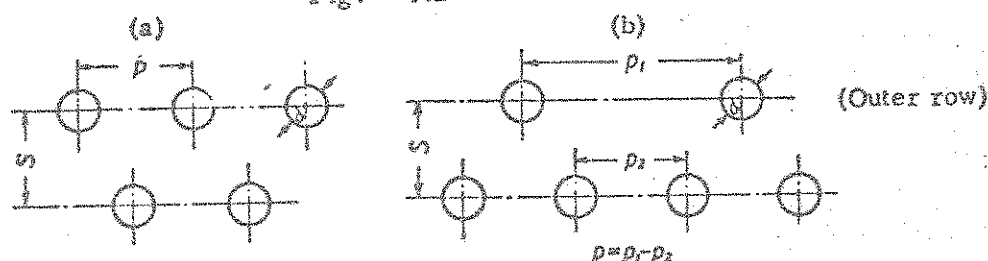
$$\text{If } \frac{p}{d} \text{ is over 4 } S \geq 2d + 0.1(p - 4d)$$

where, S : transverse pitch of the rows of the rivets (mm)

d : diameter of the rivet hole (mm)

p : pitch of the rivets in the outer row when one rivet in the inner row comes between two rivets in the outer row (mm),
or pitch of the rivets in the outer row less the pitch of the rivets in the inner row when two rivets in the inner row come between two rivets in the outer row (mm)

Fig. 4.2



- (2) For circumferential joints

$$S \geq 1.75d$$

S and d shall be as defined in 4.6 (1).

4.7 Distances between Rivet Holes and Plate Edges The distance between the centre of the rivet hole and the calking edge of the plate (measured before calking) shall be determined by the following formulas.

- (1) For longitudinal and circumferential joints of the shells (except the circumferential joints for the shells of the pressure vessels of which the heads are supported by tubes or longitudinal stays)

$$l = (1.5 \sim 1.75)d$$

- (2) For circumferential joints for the shells of the pressure vessels of which the heads are supported by tubes or longitudinal stays

$$l = (1.25 \sim 1.75)d$$

- (3) For joints other than those noted in above

$$l = (1.25 \sim 1.75)d$$

where, l : distance between the centre of the rivet hole and the plate edge (mm)

d : diameter of the rivet hole (mm)

4.8 Maximum Pitch of Rivets The pitch of a rivet shall be not larger than the value determined by the following formula.

$$p = Ct + 42$$

where, p : maximum allowable pitch (mm)
 t : thickness of the shell plate (mm)
 C : factor, given in Table 4.1.

Table 4.1

Number of rivets in pitch p	Lap or single-strap butt joints	Double-strap butt joints
1	1.30	1.75
2	2.60	3.50
3	3.45	4.60
4	4.15	5.50
5	-	6.00

4.9 Efficiency of Riveted Joints The efficiency of a riveted longitudinal joint of a shell shall be the least of the following efficiencies.

(1) Efficiency of shell plates

$$\eta_1 = \frac{p-d}{p}$$

where, η_1 : efficiency of the shell plate
 p : pitch of the rivets in the outer row (mm)
 d : diameter of the rivet hole (mm)

(2) Efficiency of rivets

$$\eta_2 = \frac{\tau a(n_1 + 1.8n_2)}{\sigma p t}$$

where, η_2 : efficiency of the rivet
 τ : shearing strength of the rivet material (kg/mm²)
 a : area of one rivet hole (mm²)
 n_1 : number of the rivets in single shear in pitch p
 n_2 : number of the rivets in double shear in pitch p
 σ : tensile strength of the shell plate (kg/mm²)
 t : thickness of the shell plate (mm)
 p : pitch of the rivets in the outer row (mm)

(3) Combined efficiency of the shell plates and the rivets, when the pitch of the rivets in the outer row is twice the pitch of the rivets in the inner row.

$$\eta_3 = \frac{p-2d}{p} + \frac{C\tau a}{\sigma p t}$$

where, η_3 : combined efficiency of the shell plate and the rivet
 C : constant, 1 for the rivets subjected to single shear or 1.8 for the rivets subjected to double shear.
 p, d, τ, a, σ and t are as defined in 4.9 (2).

Remarks: When the plates of a lap joint are not the same in thickness, the thinner plate thickness shall be taken.

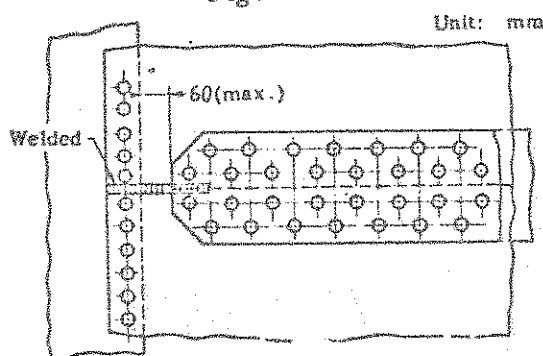
4.10 Bolted Joints The bolted joint which made by closely fitted bolting may be used instead of by riveting. In this case, the strength computations shall be done by the same manner with the riveted joints.

Remarks: When a bolt having a higher shearing strength in an elevated temperature is used, the special consideration shall be taken for the crushing strength of the plate.

4.11 Welded Joints The welded joint shall be as follows.

- (1) The joints in the pressure parts, such as a shell, head and other, shall be in compliance with the requirements specified in 13.
- (2) When the butted edges of the shell plates are welded at where the end of the buttstrap of a riveted longitudinal joint do not extend to the edges of the shell plates, the distance from the end of the buttstrap to the edge of an adjacent shell plate shall not exceed 60 mm as shown in Fig. 4.3. The carbon content of a welded plate shall not exceed 0.35 %. In this case, no radiographic examination for the welded portion is needed.

Fig. 4.3



- (3) Seal welding may be applied on the plate edge of a riveted joint, on the edge of a nozzle or a reinforcement element for an opening, on the edge of a stiffening ring, on the edge of a rivet head and on the other portion specially designated. In this case, the carbon content of a material shall not exceed 0.35 %.

4.12 Restrictions for Uses of Brazing Brazing shall not be applied to the following joints.

- (a) Joints of a shell which exceeds 25 mm in plate thickness
- (b) Longitudinal lap joints of a shell which exceeds 10 mm in plate thickness
- (c) Lap joints of a shell which exceeds 16 mm in plate thickness
- (d) Lap joints of a shell-to-head which exceeds 25 mm in plate thickness

4.13 Brazing Filler Metals The brazing filler metal shall be a nonferrous metal or an alloy thereof which the melting temperature is not less than 450° C and does not exceed that of the base metal being brazed.

4.14 Overlaps of Plates to be Brazed The dimension of the overlapping of a plates to be brazed (inclusive the portion at which the buttstrap overlaps to each edge of the shell plate) shall be not less than the followings, appropriately to the type of a joint.

Longitudinal joints	8 times the thickness of the shell plate
Circumferential joints	4 times the thickness of the shell plate

4.15 Strength of Brazing The strength of brazing shall be as follows.

- (1) Efficiency of a brazing joint shall be not more than 80 %.
- (2) Efficiency of a brazing joint of dissimilar materials shall be based on the weaker material.
- (3) Shearing strength of a brazing portion shall be 7 kg/mm².

4.16 Thickness of Buttstraps in Brazing Joints The thickness of a brazing buttstrap used in a shell shall be determined by the following formula.

$$t_s = 0.6 t + 2$$

where, t : minimum required thickness of the buttstrap (mm);
 when a corrosion allowance is considered for the shell plate, the same amount of the allowance shall be added to the inner buttstrap.

t_s : required thickness of the shell plate (mm)

5. Shells

5.1 Minimum Thickness of Plates The minimum thickness of a plate in a shell or any other portion subjected to the pressure shall be as follows.

- (1) Carbon Steel Plates and Low-Alloy Steel Plates 3 mm for plates having a welded joint, 5 mm for plates having a riveted joint

Remarks: The minimum thickness shall be that not including corrosion allowances.

- (2) High-Alloy Steel Plates 1.5 mm for plates not expected corrosions, 2.5 mm for plates expected corrosions

- (3) Nonferrous Plates 1.5 mm for plates having a welded joint and not expected corrosions, 2.5 mm for plates having a welded joint and expected corrosions, 5 mm for plates having a riveted joint

Remarks: A brazed joint is considered as welded joint.

5.2 Cylindrical Shells and Spheres under Internal Pressure The strength of a cylindrical shell and a sphere under internal pressure shall be as follows.

- (1) The minimum required thickness or the maximum allowable working pressure of a cylindrical shell or a sphere under internal pressure shall be determined by the following formulas.

(a) Cylindrical shell

$$\left. \begin{aligned} t &= \frac{PD}{200 \sigma x \eta - 1.2P} + a \\ P &= \frac{200 \sigma x \eta (t - a)}{D + 1.2(t - a)} \end{aligned} \right\} \text{Basing on the inside diameter}$$

$$\left. \begin{aligned} t &= \frac{PD_o}{200 \sigma x \eta + 0.8P} + a \\ P &= \frac{200 \sigma x \eta (t - a)}{D_o - 0.8(t - a)} \end{aligned} \right\} \text{Basing on the outside diameter}$$

where, t : minimum thickness of the plate (mm)

P : maximum allowable working pressure (kg/cm²)

D : inside diameter of the shell (mm)

D_o : outside diameter of the shell (mm)

σ : tensile strength of the material (kg/mm²)

z : ratio of the allowable tensile stress value to the tensile strength;
1/4 for steels and the value specified in 2.13 for steel casting;
and σ_x may use 1/2.5 of the yield strength for materials of which
the yield strength is over 70 % but not over 80 % of the tensile
strength, and 1/2.8 of the yield strength for materials of which the
yield strength is over 80 % of the tensile strength. However, where
the allowable stress value for an elevated temperature is given, σ_x
shall be the value thereof.

η : efficiency of the longitudinal joint or of the ligaments between
unreinforced multiple openings.

a : corrosion allowance; not less than 1 mm for carbon steels and low-
alloy steels. However, it may 0 for stainless steels, other corro-
sion-resistant materials or for special cases that no corrosion is
expected.

Remarks 1. For low-temperature operation, special considerations shall be taken
to determine an allowable stress value (σ_x) accordingly to the material
used.

2. The formulas basing on the outside diameter shall be applied to the
pipe.

(b) Spheres

$$t = \frac{PD}{400\sigma_x\eta - 0.4P} + a$$

$$P = \frac{400\sigma_x\eta(t-a)}{D + 0.4(t-a)}$$

where, D : inside diameter of the sphere (mm)

η : efficiency of the joints of the sphere

t, P, σ, η and a are as defined in 5.2 (1) (a).

(2) The minimum required thickness for the cylindrical shell under internal pressure of
which the plate thickness exceeds 1/2 of the inside radius, or for the sphere under
internal pressure of which the plate thickness exceeds 0.356 time of the inside radius,
shall be determined by the following formulas in spite of the rules in 5.2 (1) (a).
However, they shall comply with 5.2 (1), when the operating temperature exceeds
374° C.

(a) Cylindrical shell

$$\begin{cases} t = R(\sqrt{Z-1}) + a \\ Z = \frac{100\sigma_x\eta + P}{100\sigma_x\eta - P} \end{cases}$$

$$\text{or} \begin{cases} P = \frac{100\sigma_x\eta(Z-1)}{Z+1} \\ Z = \left(\frac{t-a}{R} + 1\right)^2 \end{cases}$$

where, R : inside radius of the shell (mm)

t, P, σ, η and a are as defined in 5.2 (1) (a)

(b) Sphere

$$\begin{cases} t = R \sqrt{Y - 1} + a \\ Y = \frac{2(100 \sigma x \eta + P)}{200 \sigma x \eta - P} \end{cases}$$

or

$$\begin{cases} P = \frac{200 \sigma x \eta (Y - 1)}{Y + 2} \\ Y = \left(\frac{t - a}{R} + 1 \right)^2 \end{cases}$$

where, R : inside radius of the sphere (mm)

t, P, σ, x and a are as defined in 5.2 (1) (a), and η is as defined in 5.2 (1) (b).

5.3 Circumferential joints of Shells The strength of the circumferential joint of a shell shall not be less than 50 % of the strength of the longitudinal joint. However, it may be at least 35 % of the strength of the longitudinal joint when both heads are supported by tubes or longitudinal stays and the longitudinal force acted on the circumferential joints becomes not more than 50 % of that not stayed by tubes or longitudinal stays.

5.4 Cylindrical Shells or Spheres Under External Pressure The maximum allowable working pressure of a cylindrical shell or a sphere under external pressure shall be determined by the following formulas.

(1) Cylindrical shell

$$P = \frac{BC(t-a)}{D_o}$$

where, P : maximum allowable working pressure (kg/cm²)

B : as defined in Figs. 5.1 to 5.8. l shall be the largest value of the followings. However, l shall be the distance between head-bend lines plus 1/3 of the depth of each head for the shell without stiffening ring (mm).

- (i) distance between the centres of adjacent stiffening rings (mm)
- (ii) distance from the centre of the stiffening ring near the shell end to the head-bend line plus 1/3 of the depth of the head (mm)

t : minimum thickness of the plate (mm)

D_o : outside diameter of the shell (mm)

a : corrosion allowance; not less than 1 mm for carbon steels and low-alloy steels. However, it may 0 for stainless steels, other corrosion-resistant materials or for special cases that no corrosion is expected.

C : factor, as defined in Table 5.1

Table 5.1

Type of longitudinal joint	C
Seamless or butted type	1.0
Lapped type	0.5

Remarks: For low-temperature operation, special considerations shall be taken to determine an allowable stress value (σ_x) accordingly to the material used.

(2) Sphere

$$P = \frac{BC(t-a)}{R}$$

where, R : outside radius of the sphere (mm)

P, B, C, t and a are as defined in 5.4 (1).

Remarks: In Figs. 5.1 to 5.8, the value B can be determined by the following procedures.

(1) Cylindrical shell

1. Enter the value t/D_0 at the vertical axis.
2. Determine the value $D_0/(t-a)$, assuming the thickness of the plate used.
3. Move horizontally the point t/D_0 , to the line representing $D_0/(t-a)$.
4. From this intersection, move vertically to the line for the maximum operating temperature.
5. From this intersection, move horizontally to the vertical axis B .

(2) Sphere

Enter the value $R/100(t-a)$ at the vertical axis, move horizontally to the dotted line (sphere line) and determine by the same procedure as above (1).

Fig. 5.1. Carbon Steel (Yield strength 17 kg/mm² to, but not including, 21 kg/mm²)

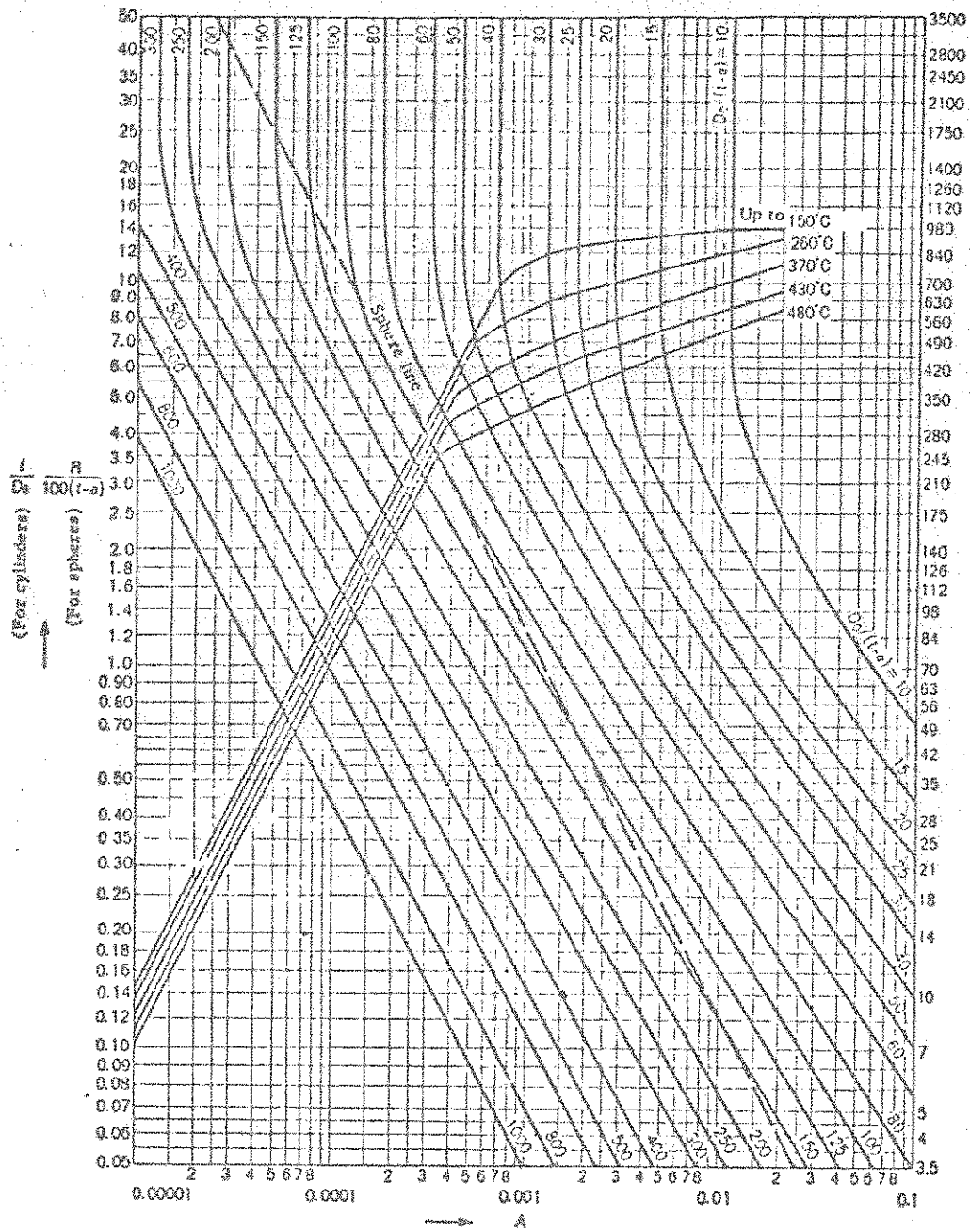


Fig. 5.2. Carbon Steel (Yield strength 21 kg/mm² to, but not including, 27 kg/mm²) and Stainless Steel (SUS 38, SUS 51)

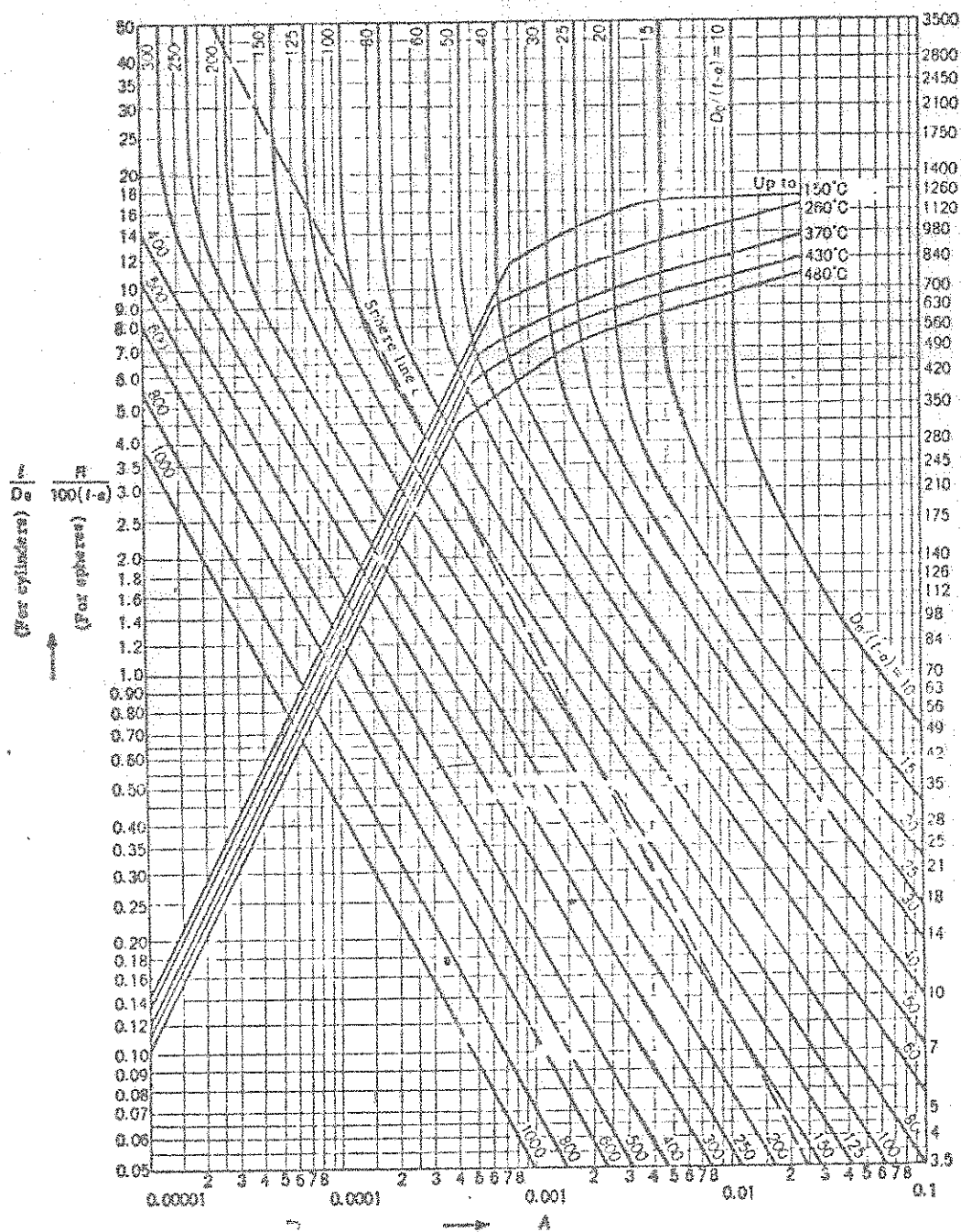


Fig. 5.3. Nickel Chromium Steel

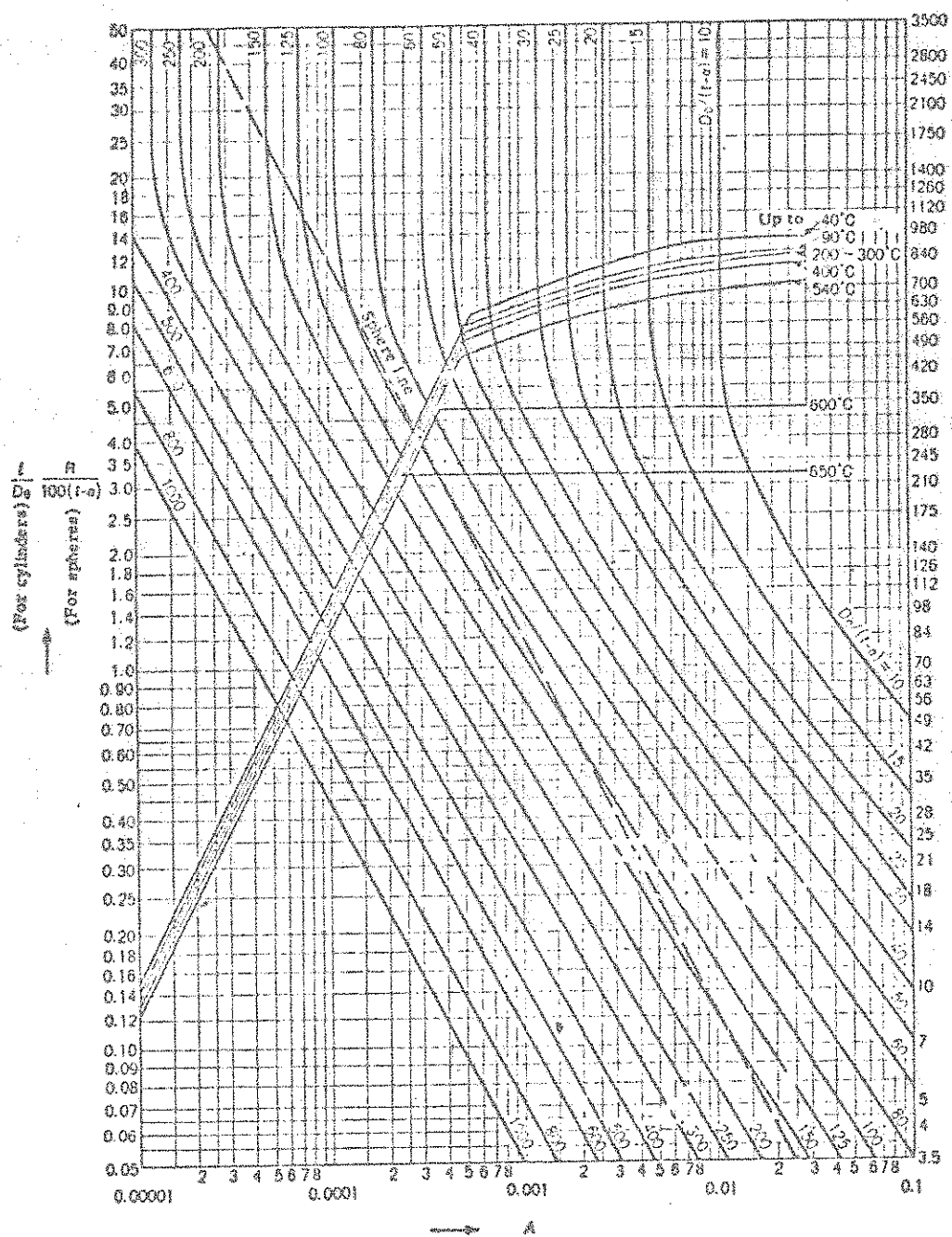


Fig. 5.4. Stainless Steel (SUS 27)

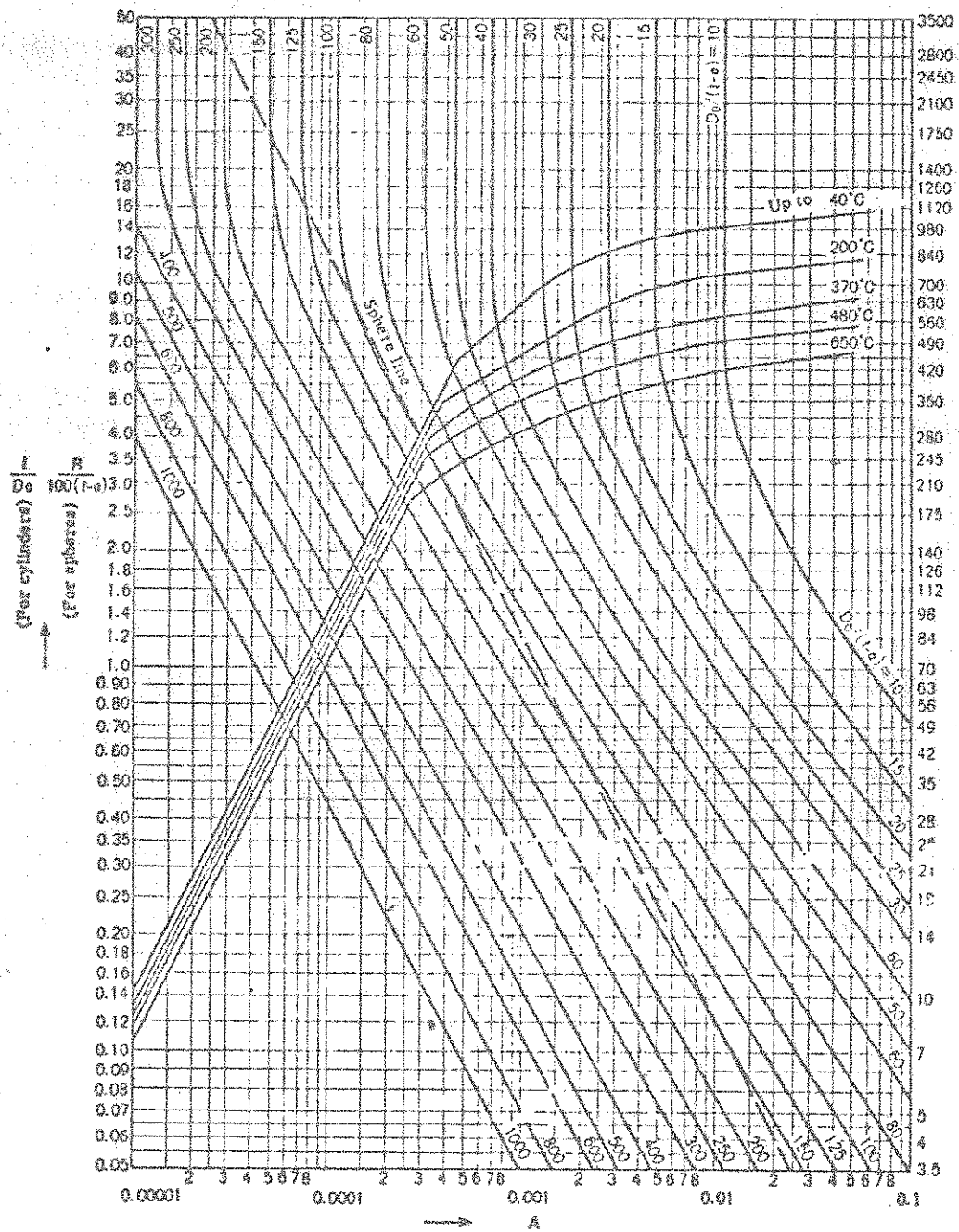


Fig. 5.5. Stainless Steel (SUS 28)

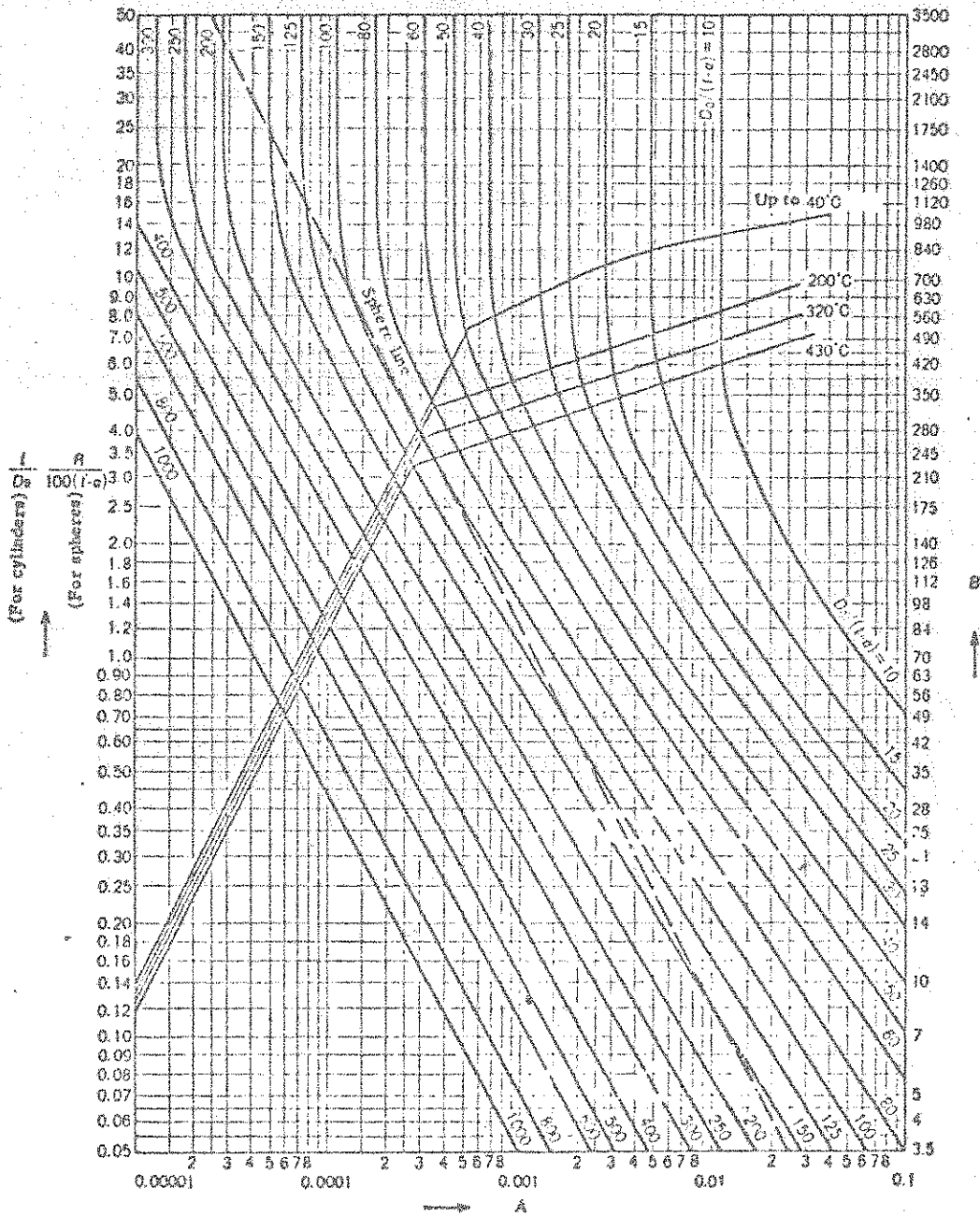


Fig. 5.6. Stainless Steel (SUS 29, SUS 32, SUS 41, SUS 42, SUS 43) SUS 41 may be used up to 590° C

