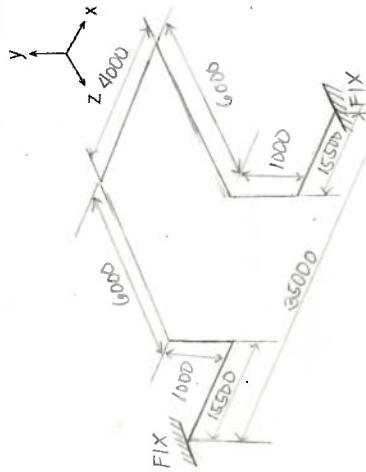


Examination Date:

Piping Schematic View



1. Check pipe bending examination
2. Calculate maximum stress (Mpa)
3. Calculate maximum force (N)

Note: A fixing point restricts to form with a uniform relation of full length only at both ends

Item

- (1) Pipe Size D = 12" B
(2) Design Temp T = 180 °C
(3) Material = Carbon Steel, Sch. 80
(4) Thermal Expansion e = 4.42 cm/m
(5) Pipe Length L = 44 m
(6) Fix - Fix Distance

$x = 35 \text{ m}, \quad y = 0 \text{ m}, \quad z = 0 \text{ m}$

$$\| \sqrt{2^2 + v^2} \|_2$$

$$U = \frac{35}{m}$$

- (7) U/D = 292 m/B
- (8) Movement of Fix YES, ☒ NO

YES

ON

- (a) Amount of Growth by Temperature
- $$\Delta x = e \times x = \underline{6.72} \pm \text{cm}$$
- $$\Delta y = e \times y = \underline{0} \pm \text{cm}$$
- $$\Delta z = e \times z = \underline{0} \pm \text{cm}$$
- (b) Amount of Displacement of a Fix Point
- $$\Delta x' = \underline{0} \pm \text{cm}$$
- $$\Delta y' = \underline{0} \pm \text{cm}$$
- $$\Delta z' = \underline{0} \pm \text{cm}$$
- Note: A mark is attached in the moving direction of a fixed point and the direction of the growth of the pipe, and is compared with them.
- (c) The Total Displacement Absorbed by the Diameter of Pipe
- $$Y = \sqrt{[(\Delta x + \Delta x')^2 + (\Delta y + \Delta y')^2 + (\Delta z + \Delta z')^2]}$$
- $$Y = \underline{6.72} \text{ cm}$$

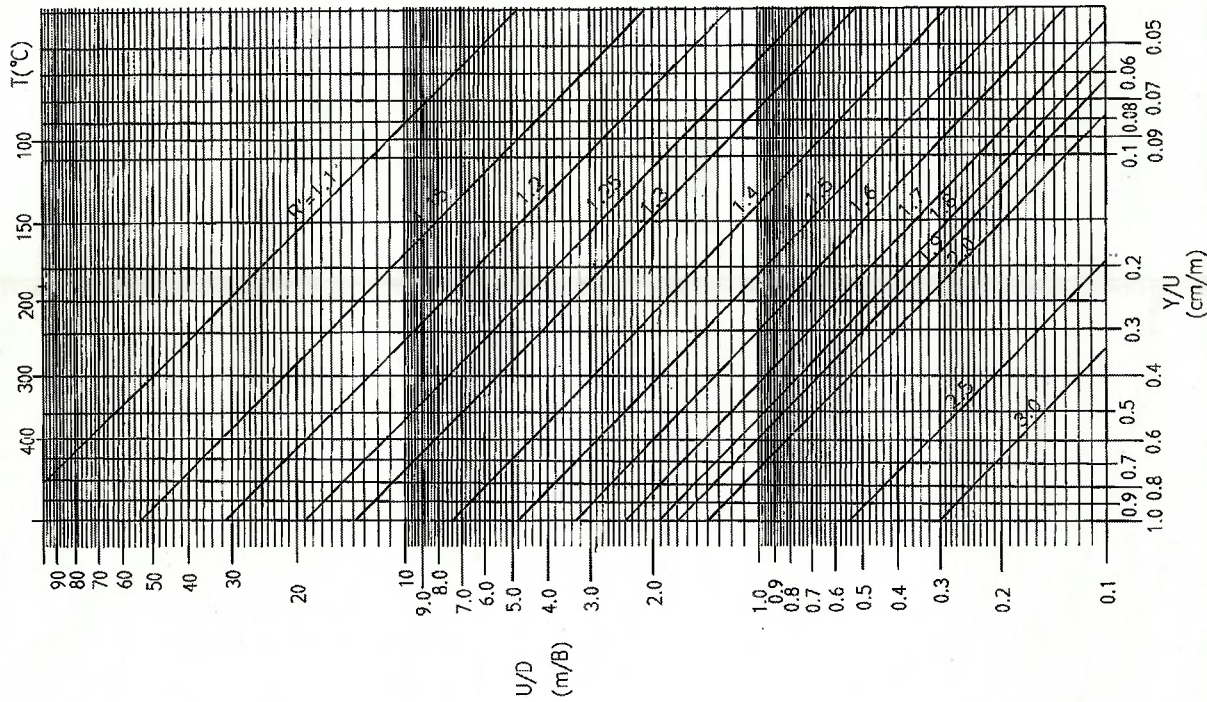
(9) It Asks for R' by U/D and Y/U from chart

$R' =$ 1.3 from R' Chart

$$(10) R = L/U \quad \underline{1.4}$$

(11) The conclusion whether detailed examination is required

$$R'/R = 0.93 \geq 1 \dots \dots \text{Required}$$



Solutions for MAX.Stress and Anchor force:	

$$1000 \text{ kg/m}^3 \left[\frac{\text{m}^3}{\text{m}^3} \right]$$

APPENDIX 2 : Simple decision table for thermal stress
簡易判定テーブル

A2.1 Simple calculation table for horizontal loop
水平ループに対する簡易計算テーブル

The maximum bending stress and anchor force for a horizontal loop is indicated in Table A2.1. The calculation condition is as follows and in case that the temperature, material, wall thickness, or dimension is changed, the table should be corrected according to para. A2.3.
水平ループに生じる最大曲げ応力およびアンカーストレスを表 A2.1 にまとめる。なお、計算条件は以下の通りとし、温度、材質、肉厚、寸法が変わる場合は A2.3 項に従って補正する。

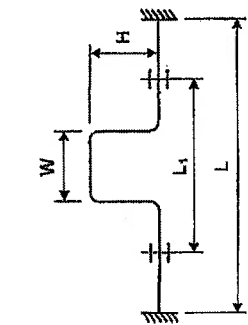


Fig. A2.1

<Calculation condition>
Pipe material : carbon steel
Pipe wall thickness : Sch.80
Calculation temperature : 200 °C
Dimensional condition : L=30m, W=1~4m, L1=8~12m
(See Fig.A2.1)
<計算条件>
配管材質 : 炭素鋼
配管肉厚 : Sch.80
計算温度 : 200 °C
寸法条件 : L=30m, W=1~4m, L1=8~12m
(図 A2.1 参照)

Table A2.1

Normal Bore	Dimension H (m)											
	2	3	4	5	6	7	8	9	10	11	12	13
2"	850 (63)	54 (530)	21 (209)	11 (106)	346 (34)	11 (106)	346 (34)	11 (106)	346 (34)	11 (106)	346 (34)	11 (106)
3"	1,220 (120)	243 (2,384)	93 (912)	48 (481)	490 (48)	48 (481)	490 (48)	48 (481)	490 (48)	48 (481)	490 (48)	48 (481)
4"	1,520 (149)	540 (5,297)	207 (2,031)	108 (1,059)	626 (61)	108 (1,059)	626 (61)	108 (1,059)	626 (61)	108 (1,059)	626 (61)	108 (1,059)
6"	2,000 (196)	1,940 (19,031)	743 (7,289)	380 (3,826)	848 (83)	380 (3,826)	848 (83)	380 (3,826)	848 (83)	380 (3,826)	848 (83)	380 (3,826)
8"	2,420 (239)	1,420 (139)	1,770 (17,364)	925 (9,074)	980 (97)	925 (9,074)	980 (97)	925 (9,074)	980 (97)	925 (9,074)	980 (97)	925 (9,074)
10"	2,850 (282)	1,550 (152)	3,810 (37,376)	2,000 (19,820)	1,090 (107)	2,000 (19,820)	1,090 (107)	2,000 (19,820)	1,090 (107)	2,000 (19,820)	1,090 (107)	2,000 (19,820)
12"	3,280 (325)	1,580 (155)	6,850 (67,199)	3,580 (35,120)	1,110 (109)	3,580 (35,120)	1,110 (109)	3,580 (35,120)	1,110 (109)	3,580 (35,120)	1,110 (109)	3,580 (35,120)
14"	3,710 (368)	1,590 (156)	9,900 (97,119)	5,200 (51,012)	1,070 (105)	5,200 (51,012)	1,070 (105)	5,200 (51,012)	1,070 (105)	5,200 (51,012)	1,070 (105)	5,200 (51,012)
16"	4,140 (411)	1,885 (185)	14,490 (142,147)	7,005 (69,119)	1,120 (110)	7,005 (69,119)	1,120 (110)	7,005 (69,119)	1,120 (110)	7,005 (69,119)	1,120 (110)	7,005 (69,119)
18"	4,570 (454)	2,230 (219)	23,540 (230,927)	1,405 (138)	1,405 (138)	1,405 (138)	1,405 (138)	1,405 (138)	1,405 (138)	1,405 (138)	1,405 (138)	1,405 (138)
20"	5,000 (497)	2,152 (211)	31,700 (310,977)	1,768 (173)	1,768 (173)	1,768 (173)	1,768 (173)	1,768 (173)	1,768 (173)	1,768 (173)	1,768 (173)	1,768 (173)
24"	5,430 (540)	2,398 (235)	60,115 (589,728)	2,268 (224)	2,268 (224)	2,268 (224)	2,268 (224)	2,268 (224)	2,268 (224)	2,268 (224)	2,268 (224)	2,268 (224)

S: 最大曲げ応力/Maximum bending stress (MPa) kgf/cm²

F: アンカーストレス/Anchor force (N) kgf

A2.2 Simple calculation table for the three dimensional loop
3次元ループに対する簡易計算テーブル

The maximum bending stress and anchor force for a three dimensional loop are indicated in Table A2.2. The calculation condition is as follows and in case that the temperature, material, wall thickness, or dimension is changed, the table should be corrected according to para. A2.3.
3次元ループに生じる最大曲げ応力およびアンカーストレスを表 A2.2 にまとめる。なお、計算条件は以下の通りとし、温度、材質、肉厚、寸法が変わる場合は A2.3 項に従って補正する。

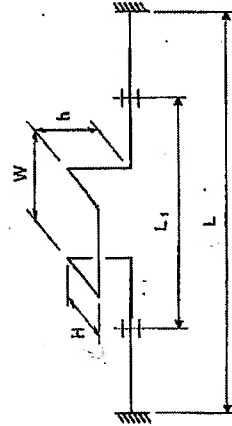


Fig. A2.2

<Calculation condition>
Pipe material : carbon steel
Pipe wall thickness : Sch.80
Calculation temperature : 200 °C
Dimensional condition : L=30m, L1=8~12m
W=1~4m (NPS 8 and below)
<計算条件>
配管材質 : 炭素鋼
配管肉厚 : Sch.80
計算温度 : 200 °C
寸法条件 : L=30m, L1=8~12m
W=1~4m (NPS 8 以下)
2~5m (NPS 10 以上) (図 A2.2 参照)

Table A2.2

Normal Bore	Dimension (m)				S (kgf/cm ²)	F (kgf)	S (kgf/cm ²)	F (kgf)	Dimension (m)	S (kgf/cm ²)	F (kgf)
	h	H	h	H							
2"	0.5	1.5	2.5	3.5	921	59	503	21	2.8	1,513	5,795
3"	0.5	1.5	2.5	3.5	921	59	503	21	3.8	1,089	3,211
4"	0.5	1.5	2.5	3.5	921	59	503	21	4.8	829	1,987
6"	0.5	1.5	2.5	3.5	921	59	503	21	5.0	776	1,804
8"	0.5	1.5	2.5	3.5	921	59	503	21	6.0	627	1,239
10"	0.5	1.5	2.5	3.5	921	59	503	21	7.0	497	843
12"	0.5	1.5	2.5	3.5	921	59	503	21	8.0	424	698
14"	0.5	1.5	2.5	3.5	921	59	503	21	9.0	338	2,890
16"	0.5	1.5	2.5	3.5	921	59	503	21	10.0	278	1,974
18"	0.5	1.5	2.5	3.5	921	59	503	21	11.0	230	1,347
20"	0.5	1.5	2.5	3.5	921	59	503	21	12.0	190	1,021
22"	0.5	1.5	2.5	3.5	921	59	503	21	13.0	160	802
24"	0.5	1.5	2.5	3.5	921	59	503	21	14.0	135	665
26"	0.5	1.5	2.5	3.5	921	59	503	21	15.0	115	565
28"	0.5	1.5	2.5	3.5	921	59	503	21	16.0	100	485
30"	0.5	1.5	2.5	3.5	921	59	503	21	17.0	88	425
32"	0.5	1.5	2.5	3.5	921	59	503	21	18.0	78	375
34"	0.5	1.5	2.5	3.5	921	59	503	21	19.0	70	335
36"	0.5	1.5	2.5	3.5	921	59	503	21	20.0	63	305
38"	0.5	1.5	2.5	3.5	921	59	503	21	21.0	57	285
40"	0.5	1.5	2.5	3.5	921	59	503	21	22.0	52	265
42"	0.5	1.5	2.5	3.5	921	59	503	21	23.0	47	245
44"	0.5	1.5	2.5	3.5	921	59	503	21	24.0	43	225
46"	0.5	1.5	2.5	3.5	921	59	503	21	25.0	40	210
48"	0.5	1.5	2.5	3.5	921	59	503	21	26.0	37	195
50"	0.5	1.5	2.5	3.5	921	59	503	21	27.0	35	185
52"	0.5	1.5	2.5	3.5	921	59	503	21	28.0	33	175
54"	0.5	1.5	2.5	3.5	921	59	503	21	29.0	31	165
56"	0.5	1.5	2.5	3.5	921	59	503	21	30.0	30	160
58"	0.5	1.5	2.5	3.5	921	59	503	21	31.0	29	155
60"	0.5	1.5	2.5	3.5	921	59	503	21	32.0	28	150
62"	0.5	1.5	2.5	3.5	921	59	503	21	33.0	27	145
64"	0.5	1.5	2.5	3.5	921	59	503	21	34.0	26	140
66"	0.5	1.5	2.5	3.5	921	59	503	21	35.0	25	135
68"	0.5	1.5	2.5	3.5	921	59	503	21	36.0	24	130
70"	0.5	1.5	2.5	3.5	921	59	503	21	37.0	23	125
72"	0.5	1.5	2.5	3.5	921	59	503	21	38.0	22	120
74"	0.5	1.5	2.5	3.5	921	59	503	21	39.0	21	115
76"	0.5	1.5	2.5	3.5	921	59	503	21	40.0	20	110
78"	0.5	1.5	2.5	3.5	921	59	503	21	41.0	19	105
80"	0.5	1.5	2.5	3.5	921	59	503	21	42.0	18	100
82"	0.5	1.5	2.5	3.5	921	59	503	21	43.0	17	95
84"	0.5	1.5	2.5	3.5	921	59	503	21	44.0	16	90
86"	0.5	1.5	2.5	3.5	921	59	503	21	45.0	15	85
88"	0.5	1.5	2.5	3.5	921	59	503	21	46.0	14	80
90"	0.5	1.5	2.5	3.5	921	59	503	21	47.0	13	75
92"	0.5	1.5	2.5	3.5	921	59	503	21	48.0	12	70
94"	0.5	1.5	2.5	3.5	921	59	503	21	49.0	11	65
96"	0.5	1.5	2.5	3.5	921	59	503	21	50.0	10	60
98"	0.5	1.5	2.5	3.5	921	59	503	21	51.0	9	55
100"	0.5	1.5	2.5	3.5	921	59	503	21	52.0	8	50
102"	0.5	1.5	2.5	3.5	921	59	503	21	53.0	7	45
104"	0.5	1.5	2.5	3.5	921	59	503	21	54.0	6	40
106"	0.5	1.5	2.5	3.5	921	59	503	21	55.0	5	35
108"	0.5	1.5	2.5	3.5	921	59	503	21	56.0	4	30
110"	0.5	1.5	2.5	3.5	921	59	503	21	57.0	3	25
112"	0.5	1.5	2.5	3.5	921	59	503	21	58.0	2	20
114"	0.5	1.5	2.5	3.5	921	59	503	21	59.0	1	15
116"	0.5	1.5	2.5	3.5	921	59	503	21	60.0	0	10
118"	0.5	1.5	2.5	3.5	921	59	503	21	61.0	0	5
120"	0.5	1.5	2.5	3.5	921	59	503	21	62.0	0	0

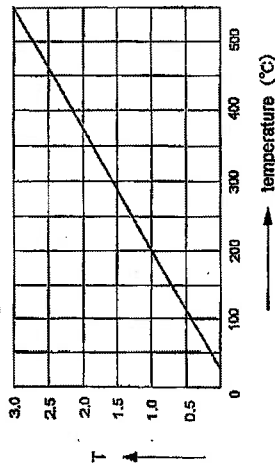
A2.3 Correction formula for the change of calculation condition 計算上条件の変更に對する補正式

In case that the calculation condition of Table A2.1 and Table A2.2 is changed, the value of the table needs to be corrected by using the following formula.

表 A2.1 および表 A2.2 において計算条件が変化する場合は、以下の式にて表中の数値を修正する。

The maximum stress : $S = (\text{indicated value}) \cdot T \cdot M \cdot L / 30$
最大曲げ応力 : $S = (\text{表示値}) \cdot T \cdot M \cdot L / 30$
Anchor force : $F = (\text{indicated value}) \cdot T \cdot M \cdot K \cdot L / 30$
アンカーフォース : $F = (\text{表示値}) \cdot T \cdot M \cdot K \cdot L / 30$

(1) Correction factor due to temperature (T)
温度による修正係数 (T)



(2) Material coefficient (M)
材料係数 (M)

For stainless steel, $M=1.43$
ステンレス鋼に対しては、 $M=1.43$ とする。

For carbon steel, $M=1.0$

(3) Correction factor due to wall thickness
配管肉厚による修正係数 (K)

呼び径 (B)	2	3	4	6	8	10	12	14	16	18	20	24
Sch.40	0.674	0.720	0.692	0.643	0.648	0.622	0.597	0.584	0.607	0.617	0.593	0.582
Sch.80	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

(4) Correction of dimension (L)
寸法の修正 (L) (fixed-to-fixed distance)

L' indicates the corrected anchor span.
変更となるアンカー間隔を L' として修正する。

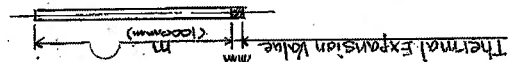


Table 1. Thermal Expansion Value mm/mm
表 1.1 金属の熱膨張係数

温度 (°C)	100	200	300	400	500	600	700	800	900	1000
鋼 (Steel)	0.012	0.014	0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030
ステンレス鋼 (Stainless Steel)	0.010	0.012	0.014	0.016	0.018	0.020	0.022	0.024	0.026	0.028
銅 (Copper)	0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030	0.032	0.034
アルミニウム (Aluminum)	0.024	0.026	0.028	0.030	0.032	0.034	0.036	0.038	0.040	0.042
鉄 (Iron)	0.011	0.013	0.015	0.017	0.019	0.021	0.023	0.025	0.027	0.029
鉛 (Lead)	0.030	0.032	0.034	0.036	0.038	0.040	0.042	0.044	0.046	0.048
ガラス (Glass)	0.005	0.006	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.014
セラミックス (Ceramics)	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.010	0.011

温度 (°C)	100	200	300	400	500	600	700	800	900	1000
鋼 (Steel)	0.012	0.014	0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030
ステンレス鋼 (Stainless Steel)	0.010	0.012	0.014	0.016	0.018	0.020	0.022	0.024	0.026	0.028
銅 (Copper)	0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.030	0.032	0.034
アルミニウム (Aluminum)	0.024	0.026	0.028	0.030	0.032	0.034	0.036	0.038	0.040	0.042
鉄 (Iron)	0.011	0.013	0.015	0.017	0.019	0.021	0.023	0.025	0.027	0.029
鉛 (Lead)	0.030	0.032	0.034	0.036	0.038	0.040	0.042	0.044	0.046	0.048
ガラス (Glass)	0.005	0.006	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.014
セラミックス (Ceramics)	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.010	0.011