DIMENSIONING OF HEATING NETWORKS PIPES

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Abstract*: The main objective of the project is to create a presentation about the main sized of supporting and clamping elements of industrial installations. These depend on diameters of pipes of industrial equipment. Therefore, prior choosing or determining construction elements of clamping and support items, there is necessary to thoroughly study all installation designs, whether electric, water, gas, rain water, compressed air, ventilation etc. according to which pipe networks have been dimensioned. Clamping and support devices with the highest constructive diversity are met at heating equipment. The specific of this type of installation is given by pipes expansion when heat transfer fluid flows. This paper develops information especially for the mechanical calculation of heating networks, i.e. calculation of pipe walls thickness and calculation between mobile and fixed supports.*

Keywords*: heating equipment, mobile and fixed supports.*

1. INTRODUCTION

The heating network is a system of branched pipes which provide heat distribution. The size of this network may vary according to the area served, from the ground surface of a city, i.e. a district or building.

The mechanical calculation of heating network with steel pipes considers tension condition of the pipe material, generated by charges (loadings) with action [1]:

- permanent, generally derived from the weight of pipes and fittings;
- temporary (quasi - permanent): determined by wind, friction on mobile supports and axial compensators, of internal pressure, pretensioning etc.;
- temporary (variable): generated by rapid uneven heating of pipes, shrinkage of mobile supports etc;
- accidental – in event of earthquakes or sudden valve closing.

2. CLASSIFICATION OF HEATING SYSTEMS

Hot water at maximum temperature of 95°C will be used. The heat transfer fluid increases heating potential inside the boiler, taking over a part of heating energy transferred from the burnt fuel, and through a closed pipe network, transfers accumulated heat energy to the area to be heated, using heating surfaces.

Hot water heating systems are classified according to composition or functioning particularities [1], as follows:

a) According to temperature of heat transfer fluid at boiler outlet: hot water equipment: average temperature; rated temperature of up to 95°C; low temperature warm water installations; rated temperature up to 65°C.

b) According to how warm water circulates in the distribution network of heat transfer fluid: natural circulation equipment, known as "thermosiphon" or gravity circulation; forced circulation equipment.

c) According to the number of heat transfer agent distribution pipes: double pipe installations (bitube installations); single pipe installations (monotube installations).

d) According to clamping diagram or connection with atmosphere: open installations, provided with open expansion tank systems; closed installations, provided with closed expansion tank systems.

e) According to location of distribution pipes: lower distribution; upper distribution.
f) According to the solution of forming the distribution network: arborescent networks; radial networks; ring networks.
g) According to response level to conditions of heat and hydraulic stability: local thermo-hydraulic adjustment installations; central thermo-hydraulic adjustment installation; global energy management equipment.
h) According to the components of heat transfer to heated area: with convective surfaces (static or dynamic); convection-radiation surfaces; with radiation surfaces.

The main features of hot water heating systems are the following [1]:

- provides comfort conditions because of low temperature of surface of heating items;
- allow central or local adjustment of heat transfer fluid flows delivered to heat spaces;
- provides operation and maintenance safety;
- average life duration, because of low corrosion coating;
- presents high thermal inertia, compared to other heating systems;
- presents freezing danger, in case of absence of a protection system with attached conductors or freezing inhibitors;
- have high investment costs compared to other systems.

3. CALCULATION OF PIPE WALL THICKNESS

According to official design instructions (Instructions RT-1 M.E.E.-I.S.P.E.), thermal pipe resistance calculation is based on the method of admissible mechanic tension [1].

The thickness of pipes' wall, expressed in cm, is determined with the formula

$$s = \frac{p_i D_I}{2 \cdot \phi \cdot \sigma_a} + c \qquad (1)$$

Where: p_i is the maximum interior operating pressure (rated pressure) [daN/cm^2]; D_i – inner pipe diameter (that can be assimilated to the nominal diameter [cm]; φ – welding quality coefficient depending on the welding technology used in making the pipe (values ranged from 0.8 to 1); σ_a – admissible resistance of material related to the loading determined by the interior pressure on tangential direction [daN/cm^2], depending on the material quality.

$$\sigma_a = \sigma_r / C_s \ [\text{daN/cm}^2] \qquad (2)$$

Where: σ_r is the material's breaking resistance [daN/cm^2]; C_s – safety coefficient, equal to 3.75, for seamless pipe and 3, for welded tubes; c – addition of corrosion and wear equal to 0.05 cm for nominal diameters of $D_n \leq 250$ and of 0.1 cm for pipes of $D_n > 250$.

After calculation, the standard dimensions of tubes in the current production are selected; the tubes wall thickness being selected according to the standard value immediately higher resulted from calculation with the formula (1). Calculation for checking the tension generated by interior pressure is done by choosing the thickness of tube walls (table 1) of the current manufactured series, with the formula:

$$\sigma = \frac{p_i D_I}{2 \cdot \phi \cdot (s - c)} \leq \sigma_a \qquad (3)$$

Table 1 Sizes and weights for pipes STAS 6898 (extras)

Outer diameter [mm]	Wall thickness, [mm]						
	7,1	7,9	8,7	9,5	10,3	11,1	11,9
	Linear mass, [kg/m]						
406,4	69,91	77,73	85,32	92,98	100,61	108,20	115,77
508	87,70	97,43	107,12	116,78	126,41	136,01	145,58
610	105,56	117,30	129,00	140,18	153,32	163,93	175,54
711	123,24	136,97	150,67	164,34	177,98	191,58	205,15
813	141,10	156,84	172,56	188,24	203,88	219,50	235,09
914	158,79	176,52	194,22	211,90	229,54	247,85	264,72
1016	-	196,30	216,11	235,79	255,45	275,07	294,06
1118	-	-	237,99	259,69	281,35	302,99	324,59
1219	-	-	259,66	285,35	307,01	330,63	354,23

1321	-	-	282,00	307,25	332,92	358,55	384,16
1422	-	-	303,70	330,91	358,57	386,20	413,80
1524	-	-	325,62	355,69	384,89	415,00	444,15
1626	-	-	347,54	378,70	410,38	442,04	473,66

4. CALCULATION OF THE DISTANCE BETWEEN MOBILE AND FIXED SUPPORTS

Regardless the type of mobile supports employed (with each sliding or rolling friction) the distance between these supports is determined with the load evenly distributed continuous beam bending formula of calculation [1]:

$$l = \sqrt{\frac{10 \cdot W \cdot \sigma_{ai}}{g_t}} \text{ [cm]} \qquad (4)$$

Where: σ_{ai} is the admissible bending resistance thanks to the sole weight [daN/cm^2] with values ranged between 200 and 250 daN/cm^2 for laying down pipes in canals unable to inspect and elbows area, regardless the location, and in the other cases (airborne location and inspected canals) with values of 500... 600daN/cm^2; W – pipe section resistance module [cm^3]; g_t – total tube, water and insulation weight [daN/cm].

Values for W and g_t are give in table 2, for other pipe dimensions must be calculated according to formulas applied in strength of materials.

Table 2 Technical data for calculation of central heating pipes

Ref. no.	Diameter		Pipe wall thickness	Transversal section area [cm^2]		Pipe outer surface [m^2/m]	Inertia moment I [cm^4]	Pipe strength module W [cm^3]
	Nominal Dn (mm)	Outer De (mm)		Pipe wall A_p	Outer free A_i			
1	40	48	3,5	4,89	13,20	0,150	12,164	5,06
2	40	48	4,0	5,25	12,57	0.150	13,467	5,61
3	50	57	3,5	5,88	19,63	0,179	21,099	7,40
4	50	57	4,0	6,66	18,85	0,179	23,476	8,32
5	65	70	3,5	7,31	31,17	0,219	40,459	11,55
6	65	70	4,0	8,36	30,12	0,219	45,244	12,92
7	80	89	3,5	9,40	52,81	0,279	85,897	19,30
8	80	89	4,0	10,68	51,53	0,279	96,508	21,68
9	100	108	4,0	13,07	78,53	0,339	176,639	32,70
10	100	108	4,5	14,63	76,97	0,339	195,947	36,65
11	125	133	4,0	16,21	122,71	0,417	336,924	50,66
12	125	133	4,5	18,16	120,76	0,417	374,748	56,35
13	150	162	5,5	25,31	156,14	0,477	678,849	89,32
14	200	219	7,0	46,62	330,06	0,688	2617,36	239,02
15	200	219	8,0	53,03	326,65	0,688	2950,17	269,42
16	250	273	8,0	66,60	518,64	0,857	5841,29	427,93
17	250	273	9,0	74,64	510,70	0,857	6498,97	476,11
18	300	325	8,0	79,67	749,90	1,021	9996,09	615,14
19	300	325	9,0	89,34	740,23	1,021	11141,40	685,62
20	350	377	9,0	104,05	1012,23	1,184	11759,26	933,29
21	350	377	10,0	115,30	1000,98	1,184	19391,30	1028,71
22	400	419	7,0	90,60	1288,25	1,316	19195,60	916,23
23	400	419	8,0	103,29	1275,56	1,316	21780,40	1039,63
24	500	521	7,0	113,03	2018,86	1,636	37269,50	1430,7
25	500	521	8,0	128,93	2002,90	1,636	42348,00	1625,6
26	600	620	8,0	153,81	2865,20	1,947	71895,90	2319,2
27	700	720	8,0	178,94	3892,50	2,261	113206,30	3146,1
28	800	820	8,0	204,08	5076,90	2,576	167913,70	4095,3
29	900	920	8,0	229,21	6418,40	2,890	237899,70	5171,7
30	1000	1020	8,0	254,34	7916,90	3,202	325045,90	6373,4
31	1100	1120	10,0	348,71	9503,30	3,516	536154,80	9574,2
32	1200	1230	11,0	421,26	11461,03	3,862	781133,40	12960,5
33	1300	1330	12,0	496,88	13396,03	4,176	1077083,9	16196,7
34	1400	1430	13,0	578,72	15481,90	4,490	1450025,1	20280,1
35	1500	1530	14,0	666,38	17709,60	4,804	2044832,7	26729,8

Depending on constructive solution of mobile supports, at tubes with diameter of Dn ≥ 700 there is the possibility to increase the distance between mobile supports, by additional calculation of tube consolidation. This can be done by the increase of the inertia moment (resistance module W) of pipe section in the are of maximum bending moments; for this will be welded, in the vertical plane of the tube section, either a metal sheet rib with thickness of 10…30 mm and adequate width (Fig.1,b), or a metallic profile (Fig. 1, a).

Improvement of the resistance module is achieved by welding, at the upper side of the tube, of two metal sheet ribs, creating an angle of 15…20° with the vertical plane (Fig. 1, b). Insertion of intermediary rod supports is another solution to increase distances between supports (Fig. 2).

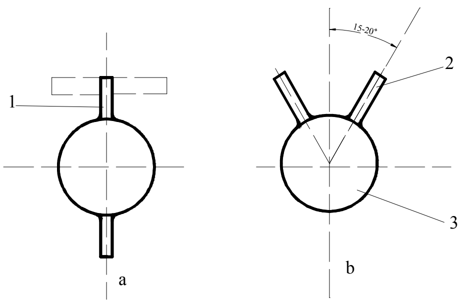

Fig. 1 Solutions to increase tubes' self - support: a - metallic profile welding; b - welding two sheet metal ribs (1 - metallic profile; 2 - rib; 3 - tube)

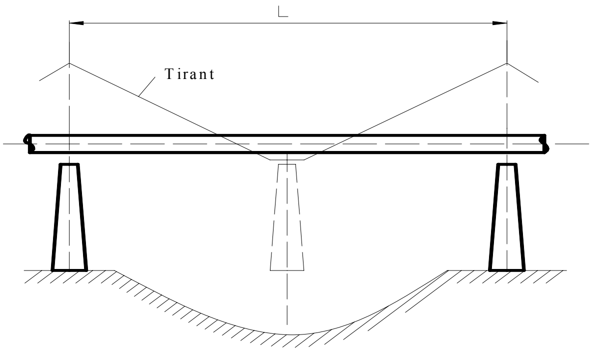

Fig. 2 Rod support of tubes

For the calculation of distance between fixed supports it is necessary to take into account the value of reaction forces generated by the expansion compensator existing between the two fixed supports. The critical buckling force (P_{cr}) is calculated considering the tube embedded in the fixed support and articulated in the compensator [1], with the formula:

$$P_{cr} = \frac{\pi^2 \cdot E \cdot I}{(0,7 \cdot L)^2} = 20,2 \cdot \frac{E \cdot I}{L^2} \text{ [daN]} \quad (5)$$

Where: E is the elasticity module of material [daN/cm^2]; I – inertia moment of pipe section [cm^4] (table 2); L – distance between fixed support and compensator [cm].

Table 3 Distances between mobile and fixed supports of heating tubes

Ref. no.	Nominal diameter [mm]	S Thickness [mm]	Distances between mobile supports, [m]					Distances between fixed supports, [m]					Remarks
			Compensators ∏			Stuffing box compensators		Compensators ∏			Stuffing box compensators		
			Canal unable to inspect	Canal to inspect	Overhead laying	Canal to inspect	Overhead laying	Canal unable to inspect	Canal to inspect	Overhead laying	Canal to inspect	Overhead laying	
						Only for hot water pipes and condensate					Only for hot water pipes and condensate		
1	40	3,5	3,0	4,5	4,0	-	-	45	50	50	-	-	Seamless pipes STAS 404
2	50	3,5	3,5	5,0	4,5	-	-	50	55	55	-	-	
3	65	3,5	4,5	5,5	5,0	-	-	55	60	60	-	-	
4	80	3,5	5,0	5,5	6,0	-	-	65	70	70	-	-	
5	100	4,0	5,5	7,5	7,0	-	-	70	75	75	-	-	
6	125	4,0	6,0	8,5	8,0	7,0	6,5	75	80	80	65	65	
7	150	5,5	7,0	9,5	9,0	8,0	7,5	85	90	90	70	70	
8	200	7,0	7,5	11,5	10,5	9,5	9,0	100	100	100	75	75	
9	250	8,0	8,5	13,0	12,0	11,0	10,5	100	105	105	85	85	
10	300	8,0	9,5	14,0	13,5	13,0	12,0	115	115	115	95	95	
11	350	9,0	11,0	15,0	14,5	14,0	13,5	115	135	135	105	105	
12	400	7,0	10,5	14,5	14,0	13,5	13,0	120	150	150	115	115	Helicoidally welded pipes STAS 6898
13	500	7,0	10,5	15,5	15,0	13,5	13,0	125	160	160	130	130	
14	600	8,0	11,5	16,5	16,0	13,5	13,0	125	170	170	140	140	
15	700	8,0	12,0	17,0	16,5	13,5	13,0	130	170	170	140	140	
16	800	8,0	12,5	18,0	17,5	14,5	14,0	130	180	180	150	150	
17	900	8,0	13,0	19,0	18,5	15,0	14,5	135	180	180	150	150	
18	1000	8,0	13,5	20,0	18,5	16,0	15,0	135	200	200	160	160	

19	1100	10,0	14,0	21,0	20,0	16,5	15,5	140	205	205	160	160	Longitudinally welded pipes STAS 7656, 7657
20	1200	11,0	15,0	22,5	21,5	16,5	16,0	140	210	210	160	160	
21	1300	12,0	15,5	24,0	23,0	17,0	16,5	150	215	215	160	160	
22	1400	13,0	16,0	25,0	24,0	17,0	16,5	150	220	220	160	160	
23	1500	14,0	17,0	27,0	25,5	17,5	17,0	160	225	225	160	160	

Under the condition for the critical buckling force to be higher than the compensator reaction force will be determined the limit distance between fixed support and compensator. These limit distances are given (table 3) for curved compensators of U shape and axial expansion joint ones.

The variety of tubes and multiple versions of design of installations, lead to the need to dimension support elements of networks examined herein.

The specific of these networks consists of temperature variations or pressure variations to which tubes are subject.

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