TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 57, Issue III, September, 2014

CLOSED EXPANSION VESSEL DIMENSIONING - PART I

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Abstract: *In order to calculate the correct volume of a closed expansion vessel, it is required to determine the water volume in the water heating system. The purpose of this paper is to bring to the attention of specialists the proposal of a new calculation formula, used to determine the volume of water in heating plants various equipment. This formula is also meant to achieve a superior level of precision when compared to the old formulas.*
Key words*: closed expansion vessel, water volume, boiler, heating equipment.*

1. INTRODUCTION

In order to calculate the capacity of a closed expansion vessel it is necessary to calculate the water volume of the heating system, often determined through estimative formulas leading to exaggerated results. The modern equipment of the heating plant, the diversity of the used systems and the heating elements lead to diminished results of their volumes when compared to the values obtained in classic formulas, leading to over sized closed expansion vessels.

This study brings to the attention of experts a new synthetic method used to calculate the volume of the heating water, which would lead to more precise results than in the classical approach. The current stage of the study refers to the heating plants with medium heating power of either hundreds or thousands of kW.

This research focuses on the calculation of the estimated water volume of the heating plant - CT, which includes:

- hot water boilers - CZ;
- tank equalizer - BEP;
- supply/return manifold – D/C;
- boilers for the accumulation of domestic hot water or plate heat exchangers and accumulation recipients for domestic hot water - ACM;
- supply and return pipes inside a heating plant - COND.

2. WATER VOLUME IN WATER BOILERS

Generally, during this stage of the design, the number and the heating power of the boilers – CZ, in the heating plant are known, and they may have the same or different heating powers – depending on whether it is a residential or an administrative building and depending on the necessary load of domestic hot water particularly during summertime, respectively in the case of the industrial halls taking into consideration the amount of technological hot water used (generally the amount used is constant all year round).

2.1 Boilers using gas or liquid fuel [1, 2]

a. <u>The boilers of the heating plant are known</u>

In the case when the boilers are specified, the technical sheet indicates their water volume: Vcz, in [1]. However, with most of the boilers it is necessary to recirculate about 33% of the hot water flow, either by using a by-pass pump or a three way mixing valve, as shown in figure 1.

By analysing a number of boiler dimensions with different heating loads: Qcz_i, in [kW], corresponding to boiler "i", with values between 100 and 1,000 kW, the following parameters have been obtained:

- recirculation volumetric flow 33 %:

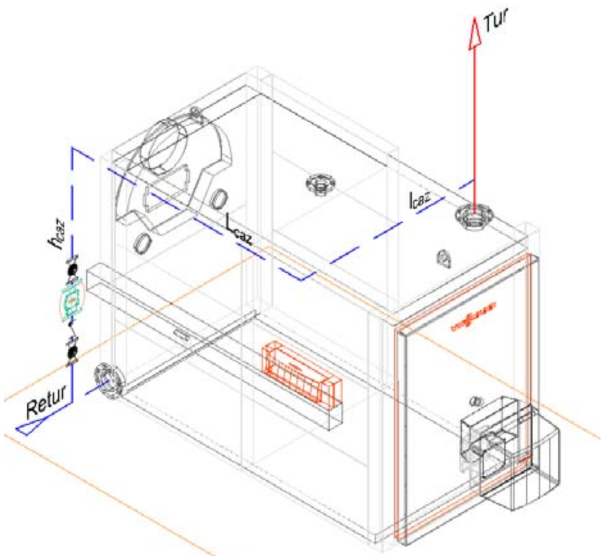

Fig. 1 Hot water boiler - by-pass pipe

$$D^{v}_{Czi\,rec} = \frac{0.33 \cdot Q_{CZi}}{\rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}$$, in [m³/s];

- recirculation pipe passage cross section:

$$S^{tr}_{Czirec} = \frac{0.33 \cdot Q_{CZi}}{w \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}$$, in [m²];

- unitary length of the recirculation pipe:

$$L^{u}_{Czi_{rec}} = \frac{L_{Czi_{rec}}}{Q_{CZi}}$$, in [m/kW];

It ddefines as the ratio between the length of the recirculation pipe and the heating load of the boiler. The worst case in this situation would happen if the supply/return connections to the boiler are exactly contrary one to another. In this case, the length of the recirculation pipe is the sum between the length, the width and the height of the boiler. The values of the unitary length of the recirculation pipe as calculated for different types of boilers are shown in table 1;

- the water volume of the recirculation:

$$V_{rec} = 1{,}000 \cdot \frac{0.33 \cdot Q_{CZi}}{w \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})} \cdot L^{u}_{CZi_{rec}} \cdot Q_{CZi} \qquad [1] \qquad (1)$$

where it was chosen: w=0.6 m/s, Δt=20 ^{0}C, resulting the water volume of the recirculation pipe for the heating loads of the analysed boilers.

The increase coefficient of the boiler's water volume due to recirculation is defined:

$$C_{rec} = \frac{V_{CZi} + V_{rec}}{V_{CZi}}$$, [adim];

with the maximum value being C_{rec}= 1.04.

By applying the same rule to the whole heating plant, with a total power Q^{CT}_{INST}, in [kW], it was considered the maximum value of the unitary volume of the water in the boiler (increased with the value of the correction owed to recirculation) and it was determined the water volume in the plant's boilers, using the formula [1]: $V^{CT}_{CZ} = 2.08 \cdot Q^{CT}_{INST}$.

The volume of the water in boilers using gas or liquid fuel in the heating plant can be determined using one of the following formulas [1]:

$$V^{CT}_{CZ} = \begin{cases} C_{rec} \cdot \sum V_{CZi} = 1.04 \cdot \sum V_{CZi} \\ 2.08 \cdot Q^{CT}_{INST} \end{cases} . \qquad (2)$$

Table 1

The water volume of the boilers

Type of boiler	Heating load		Unitary water volumes		Unitary lenght recirculation		Unitary water volume recirculation		Incr. coeff. water vol. boilers	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
	kW	kW	l/kW	l/kW	m/kW	m/kW	l/kW	l/kW		
Vitorond 100	40	100	1.02	1.25	0.031	0.065	0.017	0.021	1.014	1.021
Vitorond 200	125	270	0.92	0.98	0.15	0.027	0.023	0.027	1.023	1.029
Vitoplex 200SX2	90	560	1.13	**2.00**	0.009	0.042	0.025	0.035	1.013	1.031
Vitoplex 200	700	1.950	1.14	1.47	0.004	0.008	0.038	0.047	1.026	**1.041**

2.2. Boilers using solid fuel

The hot water boilers using solid fuel (e.g. wood logs, briquettes, remnants, pellets) are characterize by various designs and a functional variety. In this stage of the research, the following options have been analysed:

- boilers using pellets;
- boilers using wood remnants;
- boilers using wood gasification.

a. <u>The volume of boilers using pellets</u>

The boilers using pellets are mainly characterized by continuous and automatic supply – generally by using an endless screw and pellets which light up and burn through a burner, so from a functional point of view the heating plant does not need to accumulate hot water.

In the case when the boilers are specified, the technical sheet indicates their water volume: Vcz, in [1], a value which needs to be increased due to recirculation by using the coefficient C_{rec}=1.04, using the following formula [1]: $V_{CZ}^{CT} = C_{rec} \cdot \sum V_{CZi} = 1.04 \cdot \sum V_{CZi}$.

If in this design stage the boilers in the heating plant have not been specified (only the number of the boilers and their respective heating loads are known), in order to estimate the water volumes of the boilers one must analyse various boilers of different dimensions.

The results of the estimations made in the usual range of 20-150 kW are shown in tab. 2.

By using the values in tab. 2 the unitary volume of the water in the boiler has been determined, with values between $V_{CZi}^{u} = 1.08 - 5.63$ l/kW. Using the maximum value which also needs to be increased due to recirculation, the water volume in the boilers of the heating plant can be calculated by using the following formula:

$$V_{CZ}^{CT} = 5.86 \cdot Q_{INST}^{CT}. \qquad (3)$$

Due to the diverse designs and functions of this type of boilers it is preferable to effectively choose one type in order to have the water volume of the boiler from the technical sheet V_{cz}, in [1], which needs to be increased due to recirculation by the following coefficient Crec=1.04.

b. <u>The water volume of boilers using wood remnants, briquettes or wood gasification</u>

If the boilers in the heating plants are not specified knowing only the heating loads and the number of boilers, in order to estimate their water volumes the boilers' dimensions need to by examined. Using the values shown in tab. 3, one can observe that the unitary volume of the water in the boilers with values in the following ranges:

Table 2

Water volume of boilers using pellets

Boiler name	Heating load		Water volume of the boiler		Unitary water volume	
	min.	max.	min.	max.	min.	max.
	kW	kW	l	L	l/kW	l/kW
ARCA PELETI						
GRA 30RO - 150RO	30	150	68	362	2.27	2.51
OPOP PELETI						
BIOPEL 24 – 80	24	80	50	130	1.58	2.08
BOINK 24 – 30	24	30	26	45	1.08	1.50
VITOLIGNO 300 P PELETI						
VITOLIGNO 300 P 18 – 48	18	48	100	180	3.75	**5.63**
KOB PYROMAT-DYN PELETI (boiler with wood remnants and pellets)						
PYROMAT-DYN 45 - 85	35	70	130	210	3.00	3.71

Table 3

Water volume of the boilers using logs and the buffer tank

Boiler name	Heating load		Boiler water volume		Unitary volume of water in the boiler		Unitary vol. of the accumulation recipient (I_{BT})	
	min.	max.	min.	max.	min.	max.	min.	max.
	kW	kW	l	l	l/kW	l/kW	l/kW	l/kW

Boilers with wood gasification								
ATMOS DC S	20	75	45	171	1.33	3.20	50.00	90.09
VITOLIGNO 100-S	25	80	100	300	3.75	**4.50**	50.00	**55.00**
VITOLIGNO 200-S	20	50	150	160	3.20	7.50	50.00	55.00
PYROMAT-ECO	40	170	130	300	1.76	3.25	**34.00**	54.00
Boilers using pellets or wood remnants								
PYROT	100	540	345	1510	2.80	**3.95**	**8.00**	**15.00**
PYROTEC	390	1250	1150	2482	1.99	2.95	8.00	8.50

● boilers using wood remnants:

$V_{CZi}^{u} = 1.99 - 3.95\,l/kW$, chosen value

$V_{CZi}^{u} = 3.95\ l/kW$;

● boilers using wood gasification:

$V_{CZi}^{u} = 1.33 - 4.50\,l/kW$, chosen value

$V_{CZi}^{u} = 4.50\ l/kW$;

these values also need to be increased using the recirculation coefficient: C_{rec}=1.04.

The correct operation of boilers using wood remnants and the ones using wood gasification require the instalation of a buffer tank - BT, with hot water – due to the advantages of operating the boiler using as much as possible nominal load (maximum yields, minimum fuel use) and ensuring ecological burning conditions.

The volume of the buffer tank – BT, is determined as following:

● the boilers using wood waste are generally characterized by a discontinued mechanized supply of fuel and burning on mobile fire grates (reduced thickness compared to the height of the furnace), and consequently needing a relatively small volume of the buffer tank, determined using the index for power I_{BT} = 8.0 – 15.0 l_{BT}/kW, with the maximum in the formula:

$$V_{BT}^{CT} = I_{BT} \cdot Q_{INST}^{CT} = 15.0 \cdot Q_{INST}^{CT}\ ;\quad [l] \qquad (4)$$

● the boilers using wood gasification are generally charachterized by a manual filling of the whole furnace and consequently need a significantly bigger volum of the buffer tank, also determined using the index for power I_{BT} = 34.0 – 55.0 l_{BT}/kW, with the maximum in the formula:

$$V_{BT}^{CT} = I_{BT} \cdot Q_{INST}^{CT} = 55.0 \cdot Q_{INST}^{CT}\ . \qquad (5)$$

In conclusion, the water volume of the boiler using wood as well as the volume of the buffer tank in the heating plant can be determind using one of the following formulas[l]:

$$V_{CZ}^{CT} = \begin{cases} pellets \begin{cases} 1.04 \cdot \sum V_{CZi} \\ 5.86 \cdot Q_{INST}^{CT} \end{cases} \\ wood\ \ remnants, briquettes \begin{cases} 1.04 \cdot \sum V_{CZi} + 15.0 \cdot Q_{INST}^{CT} \\ 19.11 \cdot Q_{INST}^{CT} \end{cases} \\ gasification \begin{cases} 1.04 \cdot \sum V_{CZi} + 55.0 \cdot Q_{INST}^{CT} \\ 59.68 \cdot Q_{INST}^{CT} \end{cases} \end{cases} \qquad (6)$$

3. WATER VOLUME IN THE HEATING PLANT EQUIPMENTS [1, 3]

3.1.Tank equaliser

The majority of the heating plants with medium loads have a tank equaliser - BEP, which is used to eliminate the mutual influence of the pumps in the primary circuit (boiler-tank-boiler) with the ones in the secondary circuit (supply, heating circuits, preparation of domestic hot water, return).

The dimensioning of the tank equaliser is calculated as follows: the diameter of the tank is determined in such a way that the speed of the hot water to have the value w_{BEP}=0.1 m/s, and the distance between connections must follow the rule of the 3 * d_{RAC}^{BEP} , as seen in figure 2.

In order to correctly determine the volume of the tank equaliser the following parametres have been obtained:

- total volumetric flow of primary agent:

$$D_{CT}^{v} = \frac{Q_{INST}^{CT}}{\rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}\ ,\ [m^3/s];$$

- tank equaliser passage cross section:

$$S_{BEP}^{tr}=\frac{D_{CT}^{v}}{w_{BEP}}=\frac{Q_{INST}^{CT}}{w_{BEP}\cdot\rho_{apa}\cdot c_{apa}\cdot(t_{tur}-t_{retur})},\ [m^2];$$

- cross section connection BEP:

$$S_{RAC}^{tr}=\frac{D_{CT}^{v}}{w_{RAC}}=\frac{Q_{INST}^{CT}}{w_{RAC}\cdot\rho_{apa}\cdot c_{apa}\cdot(t_{tur}-t_{retur})},\ [m^2];$$

- diameter of the supply/return connection:

$$d_{RAC}^{BEP}=\sqrt{\frac{4\cdot S_{RAC}^{tr}}{\pi}},\qquad [m];$$

- total height of the tank equaliser:

$$h_{BEP}=2\cdot 2\cdot d_{RAC}^{BEP}+3\cdot(n_{RAC}^{BEP}-1)\cdot d_{RAC}^{BEP},\ [m];$$

where: n_{RAC}^{BEP} – is the total number of the tank equaliser connections.

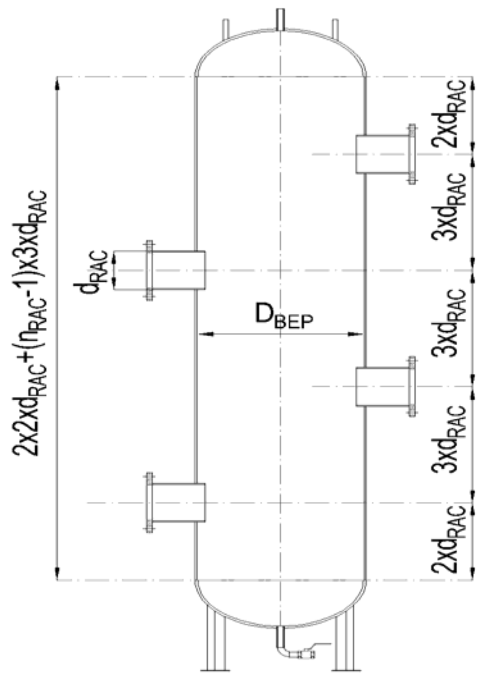

Fig 2. Tank equaliser volume

It results the water volume of the tank equaliser using this formula:

$$V_{BEP}=1{,}000\cdot S_{BEP}^{tr}\cdot h_{BEP}=$$

$$=1{,}000\cdot\frac{Q_{INST}^{CT}\cdot[4+3\cdot(n_{RAC}^{BEP}-1)]\cdot d_{RAC}^{BEP}}{w_{BEP}\cdot\rho_{apa}\cdot c_{apa}\cdot(t_{tur}-t_{retur})};\ \ [l]\ \ (7)$$

where: w_{BEP}=0.1 m/s, w_{RAC}=0.6 m/s.

In order to obtain the synthetic relation of the tank equaliser's water volume depending on the heating load of the heating plant Q_{INST}^{CT}, in [kW], and the total number of connections n_{RAC}^{BEP}, it is necessary to define the coefficient for calculating the tank equaliser's volume:

$$C_{BEP}=\frac{V_{BEP}}{Q_{INST}^{CT}\cdot n_{RAC}^{BEP}},\qquad [l/kW\cdot no\ conn];$$

determined based on the values shown in table 4, with the maximum value of C_{BEP} = 0.082 l/kW·no conn.

3.2. Supply/return manifold

The large majority of the heating plants are provided with both a supply/return manifold – D/C, which allows the centralization of commands: opening/closing, flow and temperature regulation, filling/emptying of the circuits, measuring of the parameters, etc. as seen in figure 3.

The dimensions determination of the supply/return manifold – D/C, is made using the following parametres:

Water volume of the tank equaliser *Table 4*

Name of parameter	U.M.	Rated power of the heating plant						
Total power HP	kW	100	250	500	750	1000	1250	1500
Tank equaliser diameter	mm	125	200	275	350	400	450	475
Primary conn. diameter	mm	50	80	125	150	175	175	200
Total connection number: primary 1 supply+1 return/secondary 1 supply +1 return = 4 connections								
Tank equaliser height	mm	650	1040	1625	1950	2275	2275	2600
Coefficient used for calculating the tank eq. volume C_{BEP}						**l/kW·nr rac**		**0.082**
Total connection number: primary 1 supply +1 return/secondary 2 supply +2 return = 6 connections								
Tank equaliser height	mm	950	1520	2375	2850	3325	3325	3800
Coefficient used for calculating the tank eq. volume C_{BEP}						**l/kW·nr rac**		**0.080**
Total connection number: primary 1 supply +1 return/secondary 3 supply +3 return = 8 connections								
Tank equaliser height	mm	1250	2000	3125	3750	4375	4375	5000
Coefficient used for calculating the tank eq. volume C_{BEP}						**l/kW·nr rac**		**0.079**

- D/C passage cross section:

$$S^{tr}_{D/C} = \frac{D^{v}_{CT}}{w_{D/C}} = \frac{Q^{CT}_{INST}}{w_{D/C} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}, \ [m^2];$$

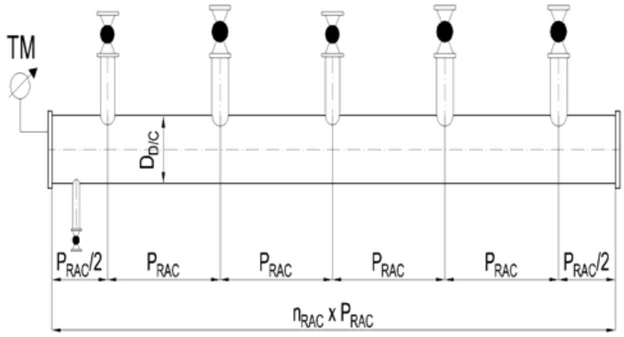

Fig. 3 Volume of the supply/return manifold

- total lenght D/C:

$$L_{D/C} = n^{D/C}_{RAC} \cdot p^{D/C}_{RAC}, \quad [m];$$

where: $p^{D/C}_{RAC}$ – the distance between the connections of the D/C, in [m]: $p^{D/C}_{RAC}$=0.4 m.

Consequently, the water volume of the supply/return manifold, results from the following formula:

$$V_{D/C} = 1{,}000 \cdot S^{tr}_{D/C} \cdot L_{D/C} = = 1{,}000 \cdot \frac{Q^{CT}_{INST} \cdot n^{D/C}_{RAC} \cdot p^{D/C}_{RAC}}{w_{D/C} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}; \quad (8)$$

where: $w_{D/C}$=0.5 m/s.

The synthetic relation of the water volume in supply+return manifold, depending on the total heating load Q^{CT}_{INST}, in [kW], and also the total number of connections $n^{D/C}_{RAC}$, involves the defining of the coefficient for calculating the volume of the supply+return manifold $C_{D+C} = \frac{2 \cdot V_{D/C}}{Q^{CT}_{INST} \cdot n^{D/C}_{RAC}}$, in [l/kW·no conn], determined based on the elements shown in table 5, with the value being: C_{D+C}=0.027 l/kW·no conn.

In conclusion, the water volume of the supply+return manifold is calculated using the formula [1]:

$$V_{D+C} = C_{D+C} \cdot Q^{CT}_{INST} \cdot n^{D/C}_{RAC} = 0.027 \cdot Q^{CT}_{INST} \cdot n^{D/C}_{RAC}. \quad (9)$$

4. WATER VOLUME OF THE PIPES INSIDE A HEATING PLANT [4, 5]

The estimation of the water volume of the pipes – COND, inside a heating plant is made by placing the equipment in an unfavorable position, as seen in figure 4, and by observing the following specific regulations:

- placing the boilers parallel with the wall with the greatest length;
- placing the tank equalizers in the exactly opposite corner;
- placing the supply/return manifold on the opposite wall at ½ of its length.

In these cases, the dimensions of the heating plants are determined by size of the boilers increased by installation distances, which are regulated both by the producer and the specific operation rules, maintenance rules, reviews and possible repairs.

The dimensions chosen this way: $L_{CZ\,maj}$, $l_{CZ\,maj}$ have been related to the heating load of the boiler, resulting the unitary (specific) dimension of the boiler, as shown in table 6:

- unitary length: $L^{u}_{CZi} = \frac{L_{CZmaji}}{Q_{CZi}}$, in [m/kW] ;
- unitary width: $l^{u}_{CZi} = \frac{l_{CZmaji}}{Q_{CZi}}$, in [m/kW] .

In line with the organisation and the placement of the equipment in a heating plant, as shown in figure 4, the total length of the pipes has been estimated, which has been subsequently increased by 30%.

Table 5

Water volume of the supply/return manifold

Name of the parameter	U.M.	Rated power heating plant						
Total power HP	kW	100	250	500	750	1000	1250	1500
Primary water flow	Kg/s	1.19	2.99	5.97	8.96	11.95	14.93	17.92
D/C diameter	mm	65	100	125	150	175	200	225
Total connection number: primary circuit 1 + 2 secondary circuit = 3 connections; $L_{D/C}$ = 1,200 mm								
Volume D+C	l	7.96	18.85	29.45	42.41	57.73	75.40	95.43
Volume D+C /kW	l/kW	0.0796	0.0753	0.0589	0.0565	0.0577	0.0603	0.0636
Coefficient for calculating water volume for D+C C_{D+C}						**l/kW·no conn**		**0.027**
Total connection number: primary circuit 1 + 3 secondary circuit = 4 connections; $L_{D/C}$ = 1,600 mm								
Volume D+C	l	10.62	25.13	39.27	56.55	76.97	100.53	127.23
Volume D+C /kW	l/kW	0.1061	0.1005	0.0785	0.0753	0.0769	0.0804	0.0848
Coefficient for calculating water volume for D+C C_{D+C}						**l/kW·no conn**		**0.027**
Total connection number: primary circuit 1 + 4 secondary circuit= 5 connections; $L_{D/C}$ = 2,000 mm								
Volume D+C	l	13.27	31.42	49.09	70.69	96.21	125.66	159.04
Volume D+C /kW	l/kW	0.1327	0.1256	0.0981	0.0942	0.0962	0.1005	0.1060
Coefficient for calculating water volume for D+C C_{D+C}						**l/kW·no conn**		**0.027**
Total connection number: primary circuit 1 + 5 secondary circuit= 6 connections; $L_{D/C}$ = 2,400 mm								
Volume D+C	l	15.93	37.70	58.90	84.82	115.45	150.80	190.85
Volume D+C /kW	l/kW	0.1592	0.1507	0.1178	0.1130	0.1154	0.1206	0.1272
Coefficient for calculating water volume for D+C C_{D+C}						**l/kW·no conn**		**0.027**

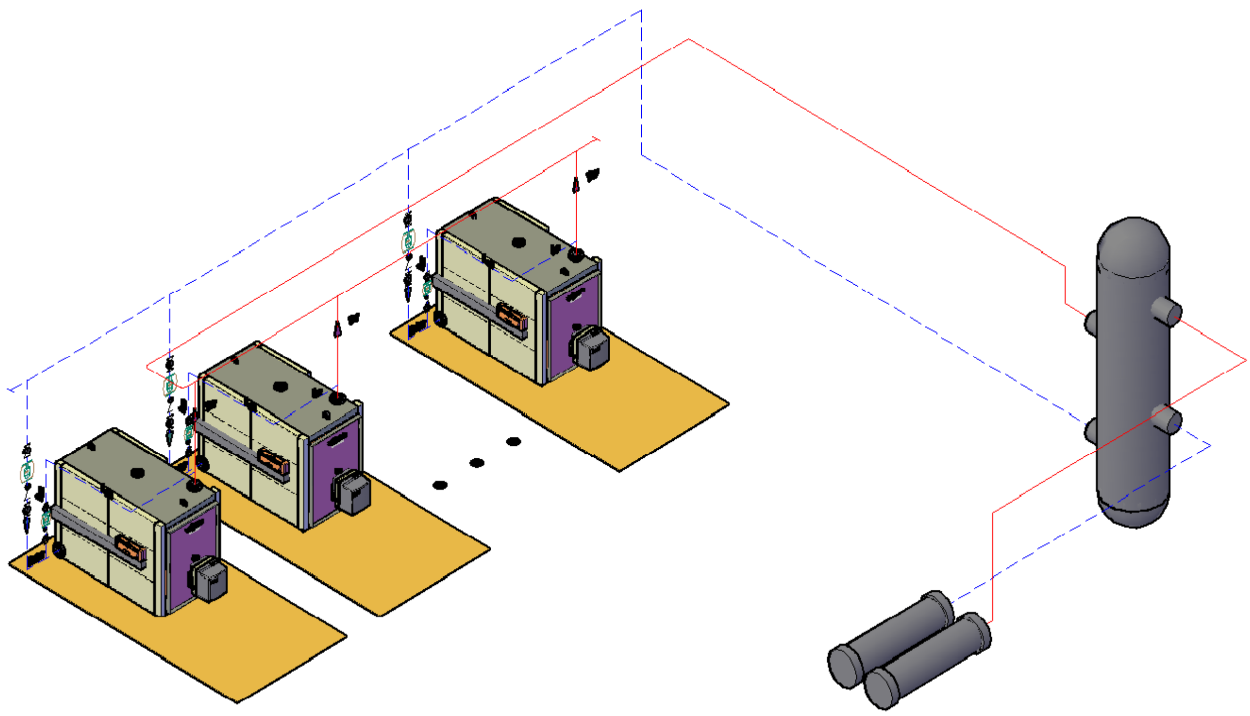

Fig. 4. Example of pipes placement

It is obtaining the following formula:

$$L^{T}_{COND} = 1.3 \cdot \left[\left(4 \cdot L^{u}_{CT} + 2 \cdot l^{u}_{CT}\right) \cdot Q^{CT}_{INST} + 12\right][m] \quad (10)$$

Consequently, in order to determine the water volume of the pipes inside the heating plant, the following parameters have been obtained:

- pipe passage cross section:

$$S^{tr}_{COND} = \frac{D^{v}_{CT}}{w_{COND}} = \frac{Q^{CT}_{INST}}{w_{COND} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}, \quad [m^2];$$

- water volume in the HP's pipes:

$$V_{COND} = 1{,}000 \cdot S_{COND}^{tr} \cdot L_{COND}^{T} =$$

$$= 1{,}000 \cdot \frac{Q_{INST}^{CT} \cdot L_{COND}^{T}}{w_{COND} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}; \quad [l] \tag{11}$$

where w_{COND} =0.6 m/s has been chosen.

The coefficient used for calculating the water volume of the pipes inside the heating plant is:

$$C_{COND} = \frac{V_{COND}}{Q_{INST}^{CT}}, \text{ in [l/kW]};$$

with a maximum value of C_{COND}=0.88 l/kW.

In conclusion, the water volume of the pipes inside the heating plant can be calculated using the following formula:

$$V_{COND} = C_{COND} \cdot Q_{INST}^{CT} = 0.88 \cdot Q_{INST}^{CT}. \quad [l] \tag{12}$$

Table 6

Water volume of pipes in the heating plants

Type of boiler		Heating load of boiler	Unitary length boiler	Unitary width boiler	Total pipe length	Pipe diameter	Unitary water volume pipes
		kW	m/kW	m/kW	m/kW	mm	l/kW
Vitorond 100	min.	40	0.031	0.016	33.2	32	0.45
	max.	100	0.060	0.039	35.6	50	0.69
Vitorond 200	min.	125	0.017	0.007	37.5	50	0.60
	max.	270	0.025	0.015	43.6	80	**0.88**
Vitoplex 200SX2	min.	90	0.008	0.004	37.5	50	0.36
	max.	560	0.036	0.020	44.1	100	0.57
Vitoplex 200	min.	700	0.003	0.002	49.5	125	0.59
	max.	1,950	0.007	0.004	56.8	200	0.80

5. WATER VOLUME OF THE EQUIPMENT FOR DOMESTIC HOT WATER

The domestic hot water is provided – ACM, by using either boilers – B, or plate heat exchanger – SPP, and domestic hot water accumulation recipients [2].

● In the case of boilers, depending on the hot water volume in the boiler coil, the coefficient used to calculate the volume of the boiler's coil is defined:

$$C_{ACM}^{B} = \frac{V_{ACM}^{B}}{Q_{ACM}^{B}}, \text{ in [l/kW]};$$

the values for the analysed boiler are shown in tab. 7, with the maximum value: $C_{ACM}^{B} = 0.23$ l/kW$_{ACM}$.

In conclusion, the water volume of the boiler's coil can be calculated using the following formula:

$$V_{ACM}^{B} = C_{ACM}^{B} \cdot Q_{ACM}^{B} = 0.23 \cdot Q_{ACM}^{B}. \quad [l] \tag{13}$$

Table 7

The water volume in the boiler's coil

Parameter name	U.M.	**Storacell**		**Horizontal/vertical SICC EVPX boilers**									
Boiler capacity	l	130	180	300	500	800	1000	1500	2000	2500	3000	4000	5000
Supply/return temp. hot/cold water temp.	^{0}C	90/70/45/12		80/70 60/12									
Transfer area	m^2	0.68	1.02	0.75	1	1.5	2	3	4	5	6	8	10
Maximum power	kW	26	39	27	32	56	74	94	150	174	200	289	336
Coil volume	l	6	9	4	5	8.5	10.5	14	19	22	24.8	33	40
Unitary volume coil	l/kW	**0.23**	**0.23**	0.15	0.16	0.15	0.14	0.15	0.13	0.13	0.12	0.11	0.12

● In the case of plate heat exchangers - SPP, the hot water used for heating can be determined by using a geometric calculation of the volume - a cuboid, as shown in this formula:

$$V_{ACM}^{SPP} = \frac{n_P - 1}{2} \cdot h_P \cdot l_P \cdot \delta_P \cdot 10^{-6}. \quad [1] \quad (14)$$

where: h_P, l_P, δ_P – are the height, length and distance between the plates, in [mm];

n_P – number of plates, determined according to the SPP's heating load.

According to the technical sheet of the plate heat exchangers - Varem dimensions Medium T2 and Large T3, for various heating powers, the number of plates and hot water volume were determined, see table 8.

In SPP's case, the coefficient used to calculate SPP's volume can be calculated using the formula:

$$C_{ACM}^{SPP} = \frac{V_{ACM}^{SPP}}{Q_{ACM}^{SPP}}, \text{ in [l/kW]};$$

with a maximum value of $C_{ACM}^{SPP} = 0.069$ l/kW$_{ACM}$.

In conclusion, the water volume of the SPP can be determined using the formula:

$$V_{ACM}^{SPP} = C_{ACM}^{SPP} \cdot Q_{ACM}^{SPP} = 0.069 \cdot Q_{ACM}^{SPP}. \quad [1] \quad (15)$$

What needs to be mentioned is that the water volume of the supply and return pipes is a primary agent – the hot water used for heating, corresponding to the boiler, respectively to the plate heat exchangers are included in the total volume of the pipes in the heating plant.

6. WATER VOLUME OF THE HEATING PLANT

In conclusion, the water volume of the boilers, equipments and pipes inside a heating plant can be determined by using one of the following formulas:

Table 8

Water volume of the plate heat exchanger

Parameter	U.M.	**VAREM Plate heat exchangers**									
Heating power SPP	kW	40	60	80	100	120	140	160	180	200	220
Supply/return temp. hot/cold water temp.	^{0}C	80/60 60/10									
Dimension	mm	**Medium T2** h/l/δ_P = 480/180/3.1 [mm]									
No. plates	pcs.	15	21	27	33	37	43	49	55	59	65
Water volume	l	1.875	2.678	3.482	4.285	4.821	5.625	6.428	7.232	7.767	8.571
Unitary water vol.	l/kW	0.047	0.045	0.044	0.043	0.040	0.040	0.040	0.040	0.039	0.039
Dimension	mm	**Large T3** h/l/δ_P = 750/350/3.5 [mm]									
No. plates	pcs.	7	9	9	11	11	13	15	15	17	17
Water volume	l	2.756	3.675	3.675	4.594	4.594	5.513	6.431	6.431	7.350	7.350
Unitary water vol.	l/kW	**0.069**	0.061	0.046	0.046	0.038	0.039	0.040	0.036	0.037	0.033

$$V_{APA}^{CT} = \begin{cases} \text{gas, liquid fuel} \begin{cases} 1.04 \cdot \sum V_{CZi} \\ 2.08 \cdot Q_{INST}^{CT} \end{cases} \\ \text{pellets} \begin{cases} 1.04 \cdot \sum V_{CZi} \\ 5.86 \cdot Q_{INST}^{CT} \end{cases} \\ \text{wood remnants, briquettes} \begin{cases} 1.04 \cdot \sum V_{CZi} + 15.0 \cdot Q_{INST}^{CT} \\ 19.11 \cdot Q_{INST}^{CT} \end{cases} \\ \text{gasification} \begin{cases} 1.04 \cdot \sum V_{CZi} + 55.0 \cdot Q_{INST}^{CT} \\ 59.68 \cdot Q_{INST}^{CT} \end{cases} \end{cases} +$$
$$+ \left(0.082 \cdot n_{RAC}^{BEP} + 0.027 \cdot n_{RAC}^{D/C} + 0.88\right) \cdot Q_{INST}^{CT} + C_{ACM} \cdot Q_{ACM} \quad [1] \quad (16)$$

Obviously, the total water volume of the central heating installation includes, beside the water volume of the heating plant, also the volume of the pipes and the distribution risers and of the heating units.

7. REFERENCES

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CALCULUL VASELOR DE EXPANSIUNE ÎNCHISE – PARTEA I

Rezumat: Dimensionarea vaselor de expansiune închise necesită calculul volumului apei calde din instalațiile de încălzire centrală. În prezenta lucrare, se propune atenției specialiştilor o nouă relație sintetică de calcul al volumului apei din utilajele şi echipamentele centralei termice, care permite determinarea acestuia cu un grad de precizie superior relațiilor clasice.

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