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CLOSED EXPANSION VESSEL DIMENSIONING - PART II

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Abstract *This paper continues with the presentation of the algorithm, used to calculate the hot water volume in water heating systems, by proposing a new mathematical formula that will determine the volume of water in horizontal and vertical pipe systems, which carry the hot water and the heating equipment. The purpose of this paper is to bring to the attention of specialists the proposition of a new calculation formula used to determine the volume of water in various equipment that form a water heating system. This formula is also meant to achieve a new and superior level of precision when compared to the old formulas.*
Key words*: closed expansion vessel, water volume, radiators/heating elements, air conditioning central units, heating equipment.*

1. INTRODUCTION

Along with the water volume of the heating plant – studied in the first part of this work [1], this article deals with the estimative calculation of water volume in the central heating systems comprising:

- water volume of the radiators/heating elements;
- water volume of heaters and heat exchangers enclosed into air handling units;
- water volume of pipings.

2. WATER VOLUME IN THE HEATING ELEMENTS

As a general rule the heating elements used in central heating systems may be: panel radiators made from steel or cast iron – especially in the existing systems, floor or ceiling coils, or through under floor/wall systems [2], [3]. Along with the water volume of the heating elements it is necessary to estimate the volume of supply/return pipes linking the heating elements to the columns. The supply of heating elements can be made either directly from columns or via manifolds.

2.1. Water Volume in radiators

For the panel radiators made of steel or cast iron, the heating load corresponds to the nominal parameters: supply/return/room temperature: 90/70/20 ^{0}C. Quite often, in the designing stage the temperature supply/return is chosen to be (t'_{tur}/t'_{retur}): 80/60 ^{0}C, thus considerably diminishing the radiator's heating load, based on the correction coefficient arising from the temperature different from the nominal value [3], according to the following formula:

$$c_t = \left(\frac{\frac{t'_{tur} + t'_{retur}}{20} - 20}{60} \right)^n ;$$

where: n – thermal exponent (adjustment) and depends on the radiator type and dimension.

Based on the water volume of panel radiators made of steel or cast iron, devised by the adjusted heat load, it results the unit water volume: V^u_{RAD}, in [l/kW], as shown in the table 1 for the steel panel radiators (usual models type 22 and 33 – having 2 or 3 panels and 2 or 3 convection sheet), respectively for cast iron radiatoars (standardized models which can be found in the systems built in the 80's) in table 2.

Table 1

Water volume for steel panel radiators

Height panel radiator	Heat load		Water volume	
	nominal 90/70/20^{0}C	adjusted 80/60/20^{0}C	radiator	unit
	W	W	l	l/kW
Panel radiator 22 L= 1,000 mm				
300	1231	965.9	3.7	3.83
400	1550	1215.8	4.4	3.62
500	1852	1452.4	5.1	3.51
600	2142	1679.2	5.8	3.45
900	2962	2312.8	8.4	3.63
Panel radiator 33 L= 1,000 mm				
300	1747	1378.8	5.3	**3.84**
400	2208	1737.9	6.4	3.68
500	2649	2079.4	7.6	3.65
600	3074	2406.4	8.7	3.62
900	4267	3328.1	12.6	3.79

Table 2

Water volume for cast iron radiators

Cast iron radiator	Heat load		Water volume	
	nominal 90/70/20^{0}C	adjusted 80/60/20^{0}C	radiator	unit
	W/el	W/el	l/el	l/kW
Cast iron radiator STAS 7363				
300/3-60	112	1.1	1.1	12.52
500/2-60	106	0.9	0.9	10.83
600/2-60	125	1.05	1.05	10.71
600/3-60	152	1.6	1.6	13.42
600/3-75	168	1.8	1.8	**13.66**
Cast iron radiator STAS 7364				
472/4	101	79.20	0.7	8.84
472/6	142	111.36	1.1	9.88
624/4	128	100.38	0.8	7.97
624/6	177	138.80	1.3	9.37
777/4	148	116.06	1.5	12.92

Therefore, the estimation of water volume in the static heating elements is based upon the unit water volume having the following maximum values:

● steel panel radiators Korado:

unit water volume: $V_{RAD}^{u} = 3.84$ l/kW;

● cast iron radiators:

unit water volume: $V_{RAD}^{u} = 13.66$ l/kW.

A special problem is the estimation of the water volume of the supply/return connection piping between the radiators and the columns which implies choosing the maximum diameter: PP-R Φ 20*2.8 mm, and estimation of the average length and of the average number of radiators, considering statistically that the average radiator has a heating load of approximately 1,000 W (adjusted according to the supply/return/room temperature: 80/60/20 ^{0}C).

The estimation of water volume of the connection pipes between the heating elements and the column, determined for the average radiator implies:

● direct connection column/radiator:

- average pipe length: 3.20 m/radiator;
- resulting the unit volume in the connection pipes: 0.517 l/kW, which added to the unit water volume in the radiator leads to an increase by the correction coefficient depending on the connection mode:

$$C_{RAC\ RAD\ PANOU}^{RAD} = 1.15;$$

$$C_{RAC\ RAD\ FONTA}^{RAD} = 1.06;$$

● connectin via manifolds:

- total average length for pipes: 19.10 m/radiator;
-resulting the unit volume in the connection pipes: 3.087 l/kW, which added to the unit water volume in radiator leads to an increase by the correction coefficient depending on the connection mode:

$$C_{RAC\ RAD\ PANOU}^{RAD} = 1.89;$$

$$C_{RAC\ RAD\ FONTA}^{RAD} = 1.38.$$

We draw the conclusion that the water volume of radiators including the connection pipes, related to the overall heat load: Q_{INST}^{RAD}, in [kW], is computed using the following formulas:

$$V_{APA}^{RAD} = \begin{cases} -\text{panel: radiator} \\ C_{RAC\ RAD\ PANOU}^{RAD} \cdot 3.84 \cdot Q_{INST}^{RAD\ PANOU} \\ -\text{cast iron radiator:} \\ C_{RAC\ RAD\ FONTA}^{RAD} \cdot 13.66 \cdot Q_{INST}^{RAD\ FONTA} \end{cases} . \text{[1] (1)}$$

2.2. Water volume in fan coils

Floor fan coils are provided with a heating coil with 3 or 4 rows of pipes, while the ceiling fan coils have 2 or 3 rows of pipes, with the minimum heat load for the lowest fan speed, corresponding to the nominal parameters: supply/return/room temperatures : 50/40/20 ^{0}C, according to the data sheet. Practically, the maximum values can be atained at the supply/return temperature of 85/75 ^{0}C, thus increasing the heat load by 250 %. As the fan coil has the same heating coil, the unit water volume is obtained at the minimum heat load. Based on the water volume of the fan coil - VCV devised by the minimum heat load, it results the unit water volume: V_{VCV}^{u}, in [l/kW], as shown in the case of a floor fan coil in table 3, respectively for ceiling fan coils in table 4.

Table 3

Water volume of floor fan coil

Fan coil type (VCV)	Heat Load 50/40/20^{0}C	Water Volume	
		VCV	unit
	W	l	l/kW
3 row coil at minimum speed			
FSC 13	1,400	0.60	0.43
FSC 23	2,300	0.90	0.39
FSC 33	3,000	1.30	0.43
FSC 43	3,650	1.60	0.44
FSC 53	4,700	1.70	0.36
FSC 63	5,500	1.90	0.35
FSC 73	6,210	1.90	0.31
4 rows coil minimum speed			
FSC 14	1,600	0.8	0.50
FSC 24	2,500	1.3	0.52
FSC 34	3,200	1.7	0.53
FSC 44	4,000	2.2	**0.55**
FSC 54	5,200	2.4	0.46
FSC 64	6,000	2.8	0.47
FSC 74	6,700	2.8	0.42

Table 4

Ceiling fan coil

Type of ceiling fan coil VCV	Heat load 50/40/20^{0}C	Water volume	
		VCV	unit
	W	l	l/kW
one row (2 pipes), minimum speed			
SKY STAR 12	2,220	1.40	0.63
SKY STAR 22	2,560	2.10	**0.82**
SKY STAR 32	3,430	2.10	0.61
SKY STAR 42	5,120	3.00	0.59
SKY STAR 52	6,130	4.00	0.65
SKY STAR 62	6,130	4.00	0.65
two rows (4 pipes), minimum speed			
SKY STAR 14	1,200	0.70	0.58
SKY STAR 24	1,200	0.70	0.58
SKY STAR 34	1,510	0.70	0.46
SKY STAR 44	3,110	1.40	0.45
SKY STAR 54	3,390	1.40	0.41
SKY STAR 64	3,390	1.40	0.41

Thus for fan coils, the maximum unit water volume of the coil is: V_{VCV}^{u}, in [l/kW]:

- Sabiana – Futura floor fan coil, unit water volume: $V_{VCV}^{u} = 0.55$ l/kW;
- Sabiana –Sky Star ceiling fan coil, unit water volume: $V_{VCV}^{u} = 0.82$ l/kW.

As in the case of the static heating elements, it is necessary to estimate the water volume of the supply/return connection pipes to the heating columns, which implies choosing the maximum pipe diameter: PP-R Φ 25*3.5 mm, and the estimation of the average pipe length. Also, the average number of fan coils is statistically estimated considering the average heat load of a fan coil to be approximately 2,300 W.

The estimation of the water volume in the connection pipes between fan coils and the columns, considering the average fan coil is as follows:

- for floor fan coil connected directly to the column:

- total average pipe length: 3.00 m/VCV;
- resulting the unit water volume in the connection: 0.332 l/kW, which cumulated with unit water volume in the fan coil, leads to an increase by the correction coefficient related to the connection mode:

$C_{RAC\ VCV\ PARD}^{VCV} = 1.60$;

- fot floor/ceiling fan coil connected via manifold:

- total average pipe length: 16.00 m/VCV;
- resulting the unit water volume in the connection pipes 1.77 l/kW, which cumulated with the unit water volume in the fan coil, leads to an increase by the correction coefficient related to the connection mode:

$C_{RAC\ VCV\ PARD}^{VCV} = 4.22$; $C_{RAC\ VCV\ TAVAN}^{VCV} = 6.84$.

In conclusion the water volume in fan coils related to the heat load Q_{INST}^{VCV}, in [kW], can be calculated using the following formulas:

$$V_{APA}^{VCV} = \begin{cases} -\text{floor VCV:} \\ C_{RAC\ VCV}^{VCV} \cdot 0.55 \cdot Q_{INST}^{VCV\ PARDOSEALA} \\ -\text{ceiling VCV:} \\ C_{RAC\ VCV}^{VCV} \cdot 0.82 \cdot Q_{INST}^{VCV\ TAVAN} \end{cases} . \quad [1]\ (2)$$

2.3. Water volume for the under floor and walls heating

The calculation of the water volume for the under floor heating piping has been conducted using the Oventrop dimensioning software, which based on the degree of the thermal insulation, flooring material and room temperature, allows the calculation of unit water volume of the heating system: V^{u}_{PARD}, in [l/kW], values shown in table 5.

Similar to the under floor heating, the walls heating systems have been calculated according with the Rehau system, which related to the plastering quality and surface temperature, allows the calculation of unit water volume of under floor heating system : V^{u}_{PER}, in [l/kW]. The resulting values are shown in table 5.

Table 5

Water volume in under floor and walls heating systems

Parameter	M.U	Under floor	
Heat flow density	W/m^2	80	97
- PE pipe	mm	16*2	
- step	mm	100	
- unit length	m/m^2	11	
Water volume	l/m^2	1.24	
Unit water volume	l/kW	**15.55**	12.83
		Wall	
Heat flow density	W/m^2	60	80
- PE pipe	mm	12*2	10,2*1,1
- step	mm	100	
- unit length	m/m^2	11	
Water volume	l/m^2	0.55	
Unit water volume	l/kW	**9.22**	6.91

Due to the lower temperature of the heating agent used in under floor and walls heating, the increase of volume expansion is significantly lower, when compared to the usual heating parameters. Considering the boiler supply temperature - minimum: 80 ^{0}C, filling temperature – minimum: 10 ^{0}C and based on water specific volumes, the correction due to lower heating agent temperature is calculated and the result is:

● under floor heating: supply temperature – maximum: 45 ^{0}C:

$$C^{t}_{PARD} = \frac{v_{45^0C} - v_{10^0C}}{v_{80^0C} - v_{10^0C}} = 0.336 ;$$

● walls heating: supply temperature – maximum 35 ^{0}C:

$$C^{t}_{PER} = \frac{v_{35^0C} - v_{10^0C}}{v_{80^0C} - v_{10^0C}} = 0.201 .$$

Therefore, the corrected heating agent volume in the under floor and walls heating systems is calculated using the following formulas:

● under floor heating:

$$V^{PARD}_{APA} = C^{t}_{PARD} \cdot V^{u}_{PARD} \cdot Q^{PARD}_{INST} = 5.25 \cdot Q^{PARD}_{INST} \text{ ;[1](3)}$$

● walls heating:

$$V^{PER}_{APA} = C^{t}_{PER} \cdot V^{u}_{PER} \cdot Q^{PER}_{INST} = 1.85 \cdot Q^{PER}_{INST} . \text{ [1] (4)}$$

The overall water volume of heating elements is calculated using the general formula:

$$V^{CI}_{APA} = \sum C^{CI}_{RAC\ CI} \cdot V^{u}_{APA} \cdot Q^{CI}_{INST} \text{ ; [1]} \quad (5)$$

where: $C^{CI}_{RAC\ CI}$ - connection correction coefficient ;

V^{u}_{APA} - unit volume of heating elements, in [l/kW];

Q^{CI}_{INST} - total heat load of different types of heating elements, in [kW], having the values summerised in table 6.

3. WATER VOLUME IN AIR HANDLING UNITS

The ventilation systems are provided with units for air conditioning which according to their usage and capacity are:

● Suspended units or duct units – having smaller capacities up to maximum 6,000 m^3/h, installed inside buildings, as a general rule inside the double ceiling or directly on to the ventilation duct. For these air handling units the heat load of the heating coils (BI) has been calculated, thus allowing the calculation of the maximum: $V^{u}_{CTA} = 0.067$ l/kW, according to the data shown in table 7.

Table 6

Summary water volume heating elements and connection coefficient

Heating element	Type of heating element	Unit water volume	Connection to column	Connection Coefficient

		V^{u}_{APA} [l/kW]		$C^{CI}_{RAC\ CI}$
Radiators	steel panel	3.84	directly to column	1.15
			using manifolds	1.89
	cast iron	13.66	directly to column	1.06
			using manifolds	1.38
Fan coils	Floor fan coil	0.55	directly to column	1.60
			using manifolds	4.22
	Ceiling fan coil	0.82	using manifolds	6.84
Under floor		5.25	using manifolds	1.00
Walls		1.85	using manifolds	1.00

Table 7

Water volume of suspended air handling units (CTA)

Type of suspended CTA		VS		NVS					
Dimension CTA		10	15	23	23	39	65	65	80
Air flow	m^3/h	1,000	2,000	1,000	2,000	3,000	4,000	5,000	6,000
Water volume BI	l	0.7	1.04	0.87	0.87	1.7	2.54	2.54	3.72
Power BI	kW	13	27	13	27	40	54	67	81
Unit water volume	l/kW	0.054	0.039	**0.067**	0.032	0.043	0.047	0.038	0.046

It is practically impossible to estimate the length of the supply pipes and the water volume for these air handling units, as they are integrated into the ventilation ducts.

Comparing the suspended units to the air handling units, it turns out that the unit water volume is about 250 % smaller than the air handling units. So, we can conclude that adding the overall heat load of the suspended units coils to the ones of the air handling units, the overall water volume can be estimated according to the formula (6).

● In most cases the air handling units CTA are installed outside the building. Due to this location the air handling unit uses as heating agent water combinned with an antifreeze agent, heated through plate heat exchangers. Therefore in the case of air handling units it is necessary to calculate the water volume of the corresponding heat exchanger, located usually in the heating plant. So, the water volume comprised in the piping is included in the heating plant equipment [1].

For the air handling units: VTS, using the Clima CAD software for dimensioning, the heat load of heating coil BI has been calculated, thus allowing to determine the size of the plate heat exchangers similar with those used for the domestic heat water [1]. Thus, the water volume has been calculated and the results are shown in table 8.

Table 8

Water volume of air handling units CTA

Type CTA		**Air handling unit VTS type VS**								
Dimension CTA		30	40	55	75	100	120	150	180	230
Air Flow	m^3/h	4,000	6,000	8,000	10,000	15,000	20,000	25,000	30,000	35,000
air/water parameters BI	^0C	exterior/heated air : - 18/22 ^0C; water BI supply/return: 80/60 ^0C								
Water volume BI	l	2.48	3.25	4.71	6.53	8.54	10.37	19.305	23.43	19.2
Power BI	kW	54	81	108	135	202	269	337	404	471
Dimension plate heat exchanger SPP	mm	**Large T3** $h/l/\delta_P$ = 750/350/3.5 [mm]								
No of plates	pcs	21	29	37	45	67	87	107	134	154
Water volume	l	9.19	12.86	16.54	20.21	30.32	39.51	48.69	61.10	70.28
Unit water volume	l/kW	**0.170**	0.159	0.153	0.150	0.150	0.147	0.144	0.151	0.149

In conclusion, in the case of the air handling unit the maximum unitary volume of water of CTA is $V^{u}_{CTA} = 0.17$ l/kW, which allows, based on the overall heating load of the coils including the suspended units: Q_{INST}^{CTA}, in [kW] to estimate the water volume related to the air handling unit as per the following formula:

$$V_{APA}^{CTA} = V_{CTA}^{u} \cdot Q_{INST}^{CTA} = 0.17 \cdot Q_{INST}^{CTA}. \quad [1] \quad (6)$$

4. WATER VOLUME IN THE CONNECTION PIPES AND COLUMNS

4.1.Water volume in columns

Analysing the heating columns where radiators are connected - column IT„i" [4], having a heat load: $Q_{INST}^{COL\ i}$, in [kW], the following parameters are resulting:

- weighted average heat load column:

$$C_{COL\ i}^{RAD} \cdot Q_{INST}^{COL\ i}, \text{ in [kW]};$$

where: $C_{COL\ i}^{RAD}$- correction coefficient of the weighted average, depending on the overall number of floors;

- volumetric heating flow water:

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

- average column cross section IT „i":

$$S_{COLi}^{tr} = \frac{D_{COLi}^{v}}{w_{COL}} = \frac{C_{COLi}^{RAD} \cdot Q_{INST}^{COLi}}{w_{COL} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}, \text{ in [m}^2\text{]};$$

- column length IT „i":

$$L_{COL\ i} = (n_{niv} - 1) \cdot h_{niv}, \text{ in [m]},$$

where: n_{niv} – building number of floors;

h_{niv} – floor height including the slab, in [m];

- column IT „i" water volume:

$$V_{APA}^{COLi} = 1000 \frac{C_{COLi}^{RAD} \cdot Q_{INST}^{COLi}}{w_{COL} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})} \cdot (n_{niv} - 1) \cdot h_{niv} \quad [1] \quad (7)$$

where: w = 0.5 m/s, $\Delta t = 20\ ^0C$, thus resulting the water volume in the column IT „i":

$$V_{APA}^{COL\ i} = 0{,}025 \cdot C_{COL\ i}^{RAD} \cdot (n_{niv} - 1) \cdot h_{niv} \cdot Q_{INST}^{COL\ i}. \quad [1] \quad (8)$$

Considering the heating system supplying the radiators, the overall water volume is calculated by adding the volume of water in all columns, as per the formula (8), thus obtaining the overall radiators heat load thus resulting the following formula:

$$V_{APA}^{COL\ RAD} = 0.025 \cdot C_{COL}^{RAD} \cdot (n_{niv} - 1) \cdot h_{niv} \cdot Q_{INST}^{RAD}. \quad [1] \quad (9)$$

A special issue is raised by the calculation of average heat load for the column for wich the average flow of heating agent is calculated. The vast majority of the central heating systems are using the distribution pipes at the lower level of the building, therefore the heat load and implicitly the flow decrease gradually from the first floor to the top ones, by succesively supplying the radiators at each floor.

As a first approximation we consider the average heat load is ½ of the overall column heat load, but the following elements have to be considered as well:

- compared to the heat load of the radiators from the intermediate floors, the radiators at the ground floor have a heat load increased by 10÷20 % (losses to soil or basement), respectively the radiators at the last floor have a heat load increased by 30÷40 % (losses through the attic or terrace);
- it is obvious that on the first section – basement - ground floor (about 0.5 m) the overall flow is circulating and the flow decreases gradually towards the last floor.

As a consequence, when calculating the average flow, the weighted heat load has to be taken into account, using the correction coefficient of weighted average, both depending on the variation of the heat load and the building's number of floors: C_{COL}^{RAD}, which in the case of radiators is summerised in table 9.

In case of columns that are supplying the fan coils, the calculation algorithm is similar, the difference being that the water temperature supply/ return is: $\Delta t = 10\ ^0C$, resulting the calculation formula for the water volume in the columns:

$$V_{APA}^{COL\ VCV} = 0.049 \cdot C_{COL}^{VCV} \cdot (n_{niv} - 1) \cdot h_{niv} \cdot Q_{INST}^{VCV}; \quad [1] \quad (10)$$

where: Q_{INST}^{VCV}- heat load of the fan coils, in [kW];

Table9

Correction coefficient of weighted average related to the number of floors

Overall number of floors		5	6	7	8	9	10	11

Radiators/Under floor/Walls	C_{COL}^{RAD}	1.119	1.097	1.082	1.071	1.063	1.056	1.051
Fan coils	C_{COL}^{VCV}	1.083	1.067	1.056	1.048	1.042	1.037	1.033

C_{COL}^{VCV} - correction coefficient of weighted average is similar to radiators, the difference being, however, that the fan coils VCV have the same heat load at all floors (as a general rule the fan coils VCV are being chosen based on the cooling capacity, therefore when it comes to heating load they are over-sized), the correction coefficient of weighted average is shown in table 9.

In the case of the columns that are supplying the under floor and walls heating systems the calculation algorithm is similar, noting that the difference between temperature supply/return is: Δt=7 ^{0}C. Also the correction due to lower temperature has to be taken into account by the coefficient previously determined, thus resulting the formula:

$$V_{APA}^{COL\ PARD/PER} = 0.024 \cdot C_{COL}^{RAD} \cdot (n_{niv} - 1) \cdot h_{niv} \cdot Q_{INST}^{PARD/PER} \quad [l] \quad (11)$$

where: C_{COL}^{RAD} - correction coefficient of weighted average is similar to the columns which are supplying the radiators, shown in table 9.

4.2. Water volume in the distribution branches

Analysing the distribution branches which are supplying the columns of the heating system – branch „i", with the heat load: $Q_{INST}^{RAM\ i}$, in [kW], the following parameters are obtained:

- volumetric heating water flow:

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

- cross section branch „i":

$$S_{RAM\ i}^{tr} = \frac{Q_{INST}^{RAM\ i}}{w_{RAM} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})}, \text{ in [m}^2\text{]};$$

- maximum possible length branch „i":

$$L_{RAM\ i} = \frac{\text{perimeter building}}{2} = \frac{P}{2}, \text{ in [m]};$$

- branch water volume „i":

$$V_{APA}^{RAM\ i} = 1000 \cdot \frac{Q_{INST}^{RAM\ i}}{w_{RAM} \cdot \rho_{apa} \cdot c_{apa} \cdot (t_{tur} - t_{retur})} \cdot \frac{P}{2} \quad [l] \quad (11)$$

where: w = 0.5 m/s, respectively Δt temperature difference based on the type of the heating elements. This allows the calculation of water volume of the „i" branch:

- for radiators: Δt=20 ^{0}C, it results:

$$V_{APA}^{RAM\ RAD\ i} = 0.025 \cdot \frac{P}{2} \cdot Q_{INST}^{RAM\ i}; \quad [l]$$

- for VCV: Δt=10 ^{0}C, it results:

$$V_{APA}^{RAM\ VCV\ i} = 0.049 \cdot \frac{P}{2} \cdot Q_{INST}^{RAM\ i}; \quad [l]$$

- for under floor/walls heating: Δt=7 ^{0}C, it results:

$$V_{APA}^{RAM\ i} = 0.025 \cdot \frac{P}{2} \cdot Q_{INST}^{RAM\ i}. \quad [l]$$

Considering the distribution that supplies the radiators/fan coils/under floor heating, the overall water volume is equal to the sum of the volumes of all branches, resulting the following formulas:

- radiators distribution:

$$V_{APA}^{DISTR\ RAD} = 0.025 \cdot \frac{P}{2} \cdot Q_{INST}^{RAD}; \quad [l] \quad (12)$$

- fan coil distribution:

$$V_{APA}^{DISTR\ VCV} = 0.049 \cdot \frac{P}{2} \cdot Q_{INST}^{VCV}; \quad [l] \quad (13)$$

- under floors/walls heating distribution:

$$V_{APA}^{DISTR\ PARD/PER} = 0.025 \cdot \frac{P}{2} \cdot Q_{INST}^{PARD/PER}. \quad [l] \quad (14)$$

It is considered that the average heat load is ½ of the overall heat load of the branch, the reason being that for safety purposes it was considered for all branches the maximum possible length ½ of the building perimeter, a value which is double on account of the supply and return pipes.

In conclusion, by summig the water volume of the columns and distribution for each type of heating element the following general formula is obtained:

$$V_{APA}^{COL+DISTRCI} = \sum\left[V_{APA}^{CDu}\left(C_{COL}^{CI}(n_{niv}-1)h_{niv}+\frac{P}{2}\right)\right]\cdot Q_{INST}^{CI}$$

[1] (15)

5. CONCLUSIONS

Based on the previously shown elements, the general formula for the calculation of the overall water volume in the heating systems, heating elements and distribution includes:

● water volume in the heating elements, in [1]:

$$V_{APA}^{CI} = \sum C_{RAC\ CI}^{CI}\cdot V_{APA}^{u}\cdot Q_{INST}^{CI};$$

● water volume in CTA, in [1]:

$$V_{APA}^{CTA} = V_{CTA}^{u}\cdot Q_{INST}^{CTA} = 0{,}17\cdot Q_{INST}^{CTA};$$

● water volume in distribution pipes, in [1]:

$$V_{APA}^{COL+DISTRCI} = \sum\left[V_{APA}^{CDu}\left(C_{COL}^{CI}(n_{niv}-1)h_{niv}+\frac{P}{2}\right)\right]\cdot Q_{INST}^{CI}$$

In the event that the proposed logical and calculation algorithm, is of interest for the experts in the field, it is necessary to expand the database related to the equipment, as well as the analysis – to the possible extent of all alternatives which are used in the heating sytems area.

6. REFERENCES

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CALCULUL VASELOR DE EXPANSIUNE ÎNCHISE – PARTEA II

Rezumat Lucrarea continuă prezentarea algoritmului de calcul al volumului apei calde din instalaţiile de încălzire centrală, prin deducerea unei noi relaţii sintetice de calcul al volumului apei din conductele orizontale, coloanele de distribuţie şi corpurile de încălzire. Se propune atenţiei specialiştilor, o nouă relaţie sintetică de calcul al volumului apei din instalaţiile de încălzire centrală, care permite determinarea acestuia cu un grad de precizie superior relaţiilor clasice.

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