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Original Research Article

ANALYSIS OF STRUCTURAL SOLUTIONS FOR RADIATORS IN BUILDINGS

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Abstract

In the following article emphasizes the analysis of technical and economic criteria for radiators, that will help you make the right choice of radiator type. Different solutions for heating flats are presented, the focus is on water-fed radiator solutions. After detailed analysis, the evaluation criteria are selected: indicators of the unit heat output of a radiator related to the mass, volume and length of the radiator QM, QV, QL. Radiator types, nominal working parameters, evaluations criteria and techno-economic analysis of structural solutions for radiators on the example of a residential building are presented.

Keywords: radiator, central heating system, indicators of the unit heat output of a radiator, technical and economic assessment, hygiene criteria, evaluation

1. INTRODUCTION

One of the basic conditions for the proper functioning of the human body, also the related development of civilization and culture of societies, is to create and maintain in rooms and buildings [1, 2] appropriate thermal conditions. In practice, this means that most often, to supply them with heat periodically (depending on the outside climate) supplying them with necessary amounts of heat to create and maintain these conditions.

The size of heat demand is so varied, if the provided room has larger or smaller heat losses to the surroundings (Fig. 1).

In the interest of lower energy bills, we are looking for various ways to save money. The heating time is reduced, the room temperature inside is lowered, etc. At the same time, it should be noted that they

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should result from the rationalization of the use of thermal energy. One of the elements that make this possible is the use of materials or construction solutions with good heating properties.

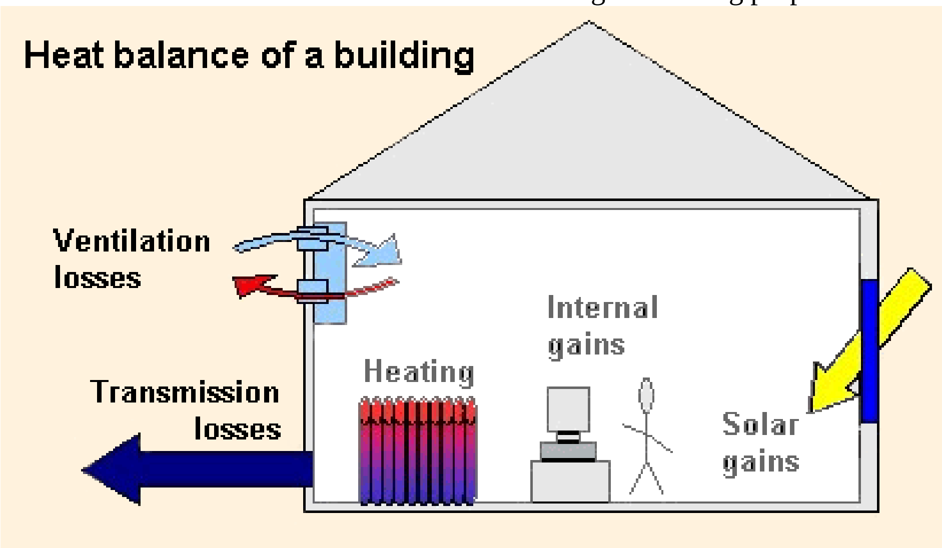


Fig. 1. The top 5 elements of the heat balance of a building [3]

Tasks and objectives set for heating systems in the construction industry are fulfilled by means of various types of heating devices and internal central heating systems with various fittings, equipment and control and regulation capabilities. The purpose of heating rooms in winter intended for human habitation is to provide people with adequate thermal conditions. In [4] is documented the results of energy consumption of buildings in a selected city, where there is a gradually thermal insulation of buildings.
Terminal elements in heating systems, at the same time, very different in terms of geometry or thermal properties [2] determining the final effect of heating, are the radiators installed in the rooms. Their task is to take over the heat obtained in boilers or heat exchangers from heating medium carried by pipes of internal heating systems and transferring it to the heated rooms.
There are a lot of companies on the market producing radiators that differ in many design solutions (different types of thermal energy carrier, heat transfer method or material used).

2. DIVISION OF RADIATORS

The most important criteria for the division of radiators [5, 6] are: method of heat transfer and the type of energy carrier and material, of which they are made, Fig. 2.
Most of the radiators available on the market and used in installations are solutions that transfer heat mainly by convection. These are sectional radiators (cast iron, steel, aluminium), radiators made of smooth pipes (e.g., vertical, horizontal, ladder) and finned tubes, convector radiators (box radiators, wall radiators, also with fan), slatted (at the plinths) and under floor heating (also with fan).
A much smaller group is made up of radiant heaters that give off heat predominantly by radiation. These are mainly so-called surface radiators placed in walls, ceilings, or floors, as well as infrared heaters and various types of radiant tape, mainly used in large halls.

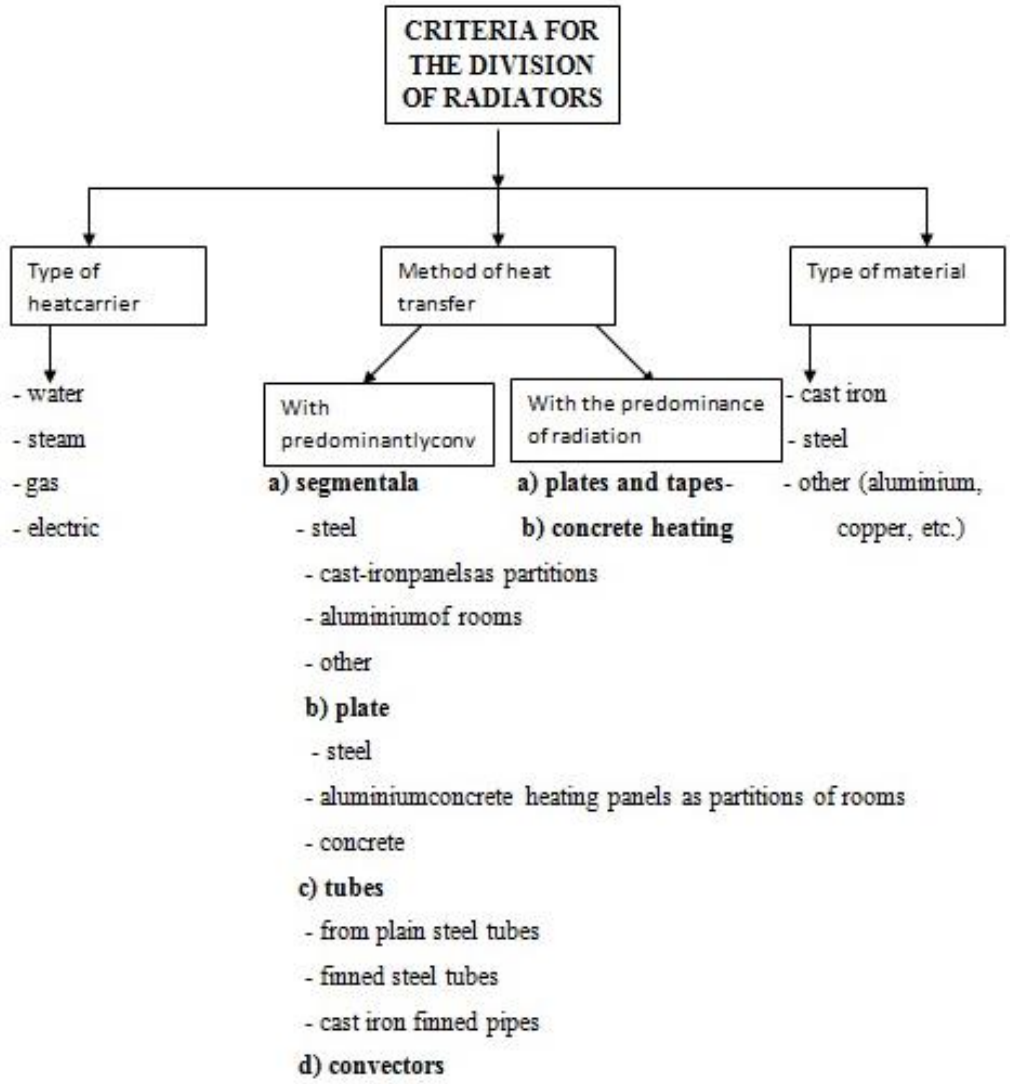


Fig. 2. Criteria for the division of radiators

3. RADIATOR EVALUATION PARAMETERS

When choosing a type of radiator, it is important to assess it in terms of economy, use and hygiene. The following requirements are placed on them:

- should be visually adapted to the room,
- in order to exclude the risk of injury, they should not have sharp edges,
- the heat output of the heater should be regulated,
- it should be easy to clean,
- should be small in size as far as possible, while still providing intensive heat exchange,
- the water volume and weight of the radiator should be as low as possible,
- should have high corrosion resistance,

– installation should be quick and easy,
– should not be expensive.

The main criteria for evaluating radiators are:

a) economic and technical criteria,
b) utility criteria,
c) hygiene criteria.

3.1 Economic and technical evaluation criteria of radiators

These are the most explicit and measurable criteria. Usually one, no more than three criteria are used to decide on the choice of a given type of radiator. Usually, two or three types of radiators are selected in the scale of the investment. If possible, radiators should be mounted on an external wall under a window. Thanks to this, the cold air flowing through the window is heated by the radiator and evenly distributed throughout the room.

The following criteria can be indicated here:

a) cost C [euro] per unit of heat transferred at nominal conditions Q_N [W]

$$C_Q = \frac{C}{Q_N} \left[\frac{euro}{W}\right], \tag{3.1}$$

b) the area A_r [m^2] of the vertical projection of the radiator, reducing the useful area of the room,

$$A_r = L(w + c)\ [m^2], \tag{3.2a}$$

where L [m] is the length of the radiator, w [m] is the width and c [m] is the clearance between the radiator and the wall (Fig. 3a). The area determined in this way does not include the necessary space around the radiator to maintain the correct conditions for convective heat exchange. Since the surfaces of the radiator niche are not included in the living space, for radiators placed in the recess (Fig. 3b), we obtain

$$A_r = L(w + c - n)\ \ [m^2]\ . \tag{3.2b}$$

If $n > w + c$, i.e., the radiator does not protrude beyond the plane of the wall, we assume $Ar = 0$. There should be free space in front of the radiator, not obstructed by furniture or non-openwork elements. The area of free space in front of the radiator mounted on the wall (Fig. 3a) can be estimated from the equation

$$A = \left(L + \pi\frac{L_1+L_2}{4}\right)(w + c + s)\ \ [m^2]\ . \tag{3.2c}$$

The area of free space in front of the radiator mounted in the recess (Fig. 3b) can be estimated from the equation

$$A = \left(L + \pi\frac{L_1+L_2}{4}\right)(w + c + s) - n(L + L_1 + L_2)\ [m^2]\ . \tag{3.2d}$$

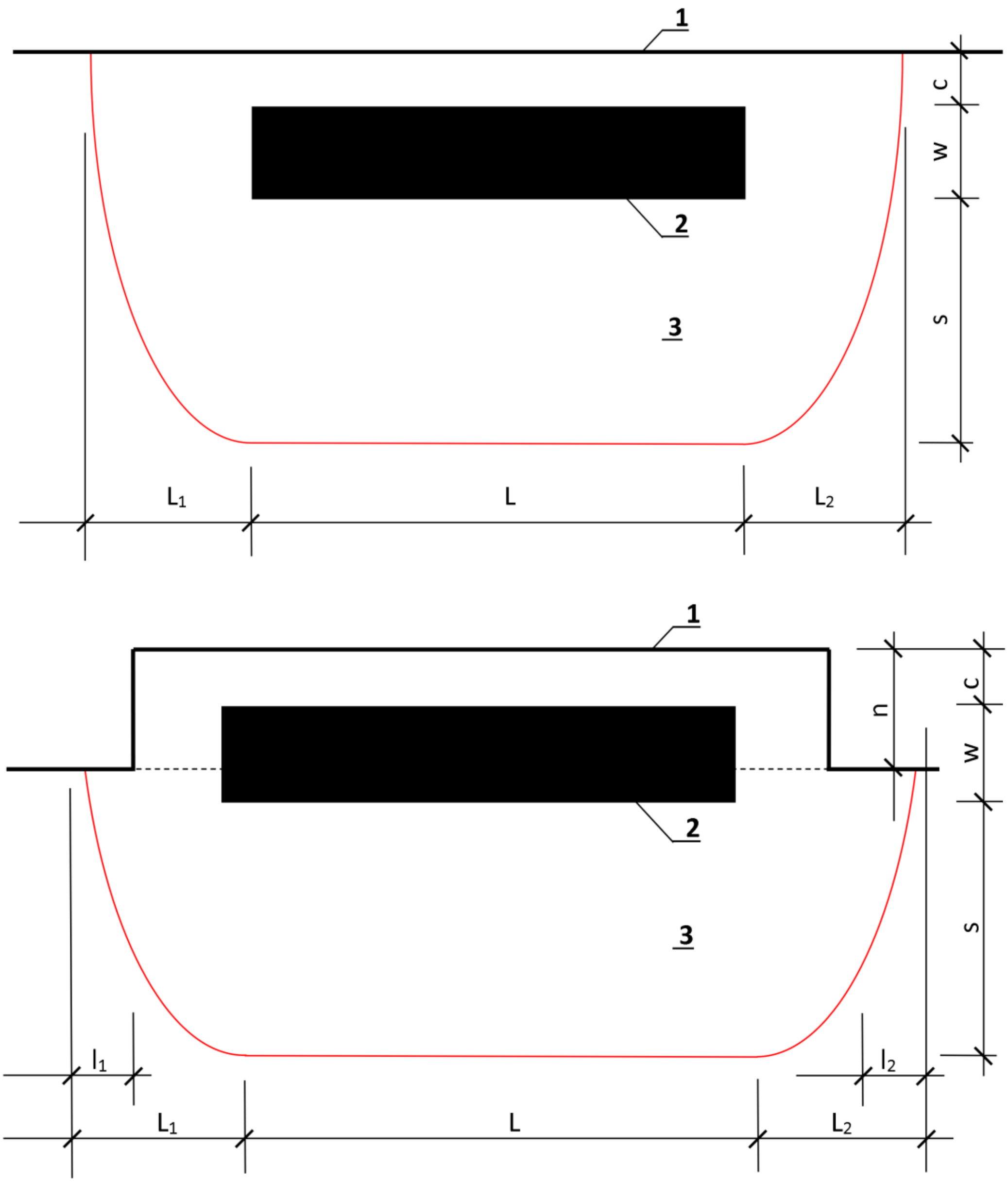
For a radiator mounted in the plane of the wall, $n = w + c$ and the above equation can be approximated as follows

$$A = \left(L + \pi\frac{L_1+L_2}{4}\right)s\ [m^2]\ . \tag{3.2e}$$

The distance c results from the radiator fixing elements used. Practically, it can be assumed that the dimension s is about 1.5 m. The L1-l1, L2-l2 distances should be as large as possible and should also provide service access and are usually 10 to 20 cm or more. The length of the radiator recess often results from the width of the window, hence the limitation of the radiator length, while maintaining the correct distances L1-l1, L2-l2.

c) the heat output Q_M [W/kg] transferred under nominal conditions Q_N [W] in relation to the weight M [kg] of the radiator (mass of material used in the construction of the heater)

$$Q_M = \frac{Q_N}{M} \left[\frac{W}{kg}\right], \tag{3.3}$$



a) b)

Fig. 3. Area occupied by the radiator in the room, 1 – wall, 2 – heater, 3 - required free space in front of the radiator. a) radiator on a flat wall, b) radiator in a niche

d) the heat output Q_L [W/m] obtained in nominal conditions Q_N [W] from a radiator in relation to the length L [m] of the radiator

$$Q_L = \frac{Q_N}{L} \left[\frac{W}{m}\right], \tag{3.4}$$

e) the heat output Q_V [W/m] obtained in nominal conditions Q_N [W] in relation to water volume of the radiator

$$Q_V = \frac{Q_N}{V} \left[\frac{W}{dm^3}\right] = \frac{Q_N}{V} \left[\frac{kW}{m^3}\right], \tag{3.5}$$

f) the type of connection is a very important criterion when we want to replace the radiator or carry out a small renovation. There is a choice of side or bottom connection. It is worth remembering that the radiators also differ in the spacing and diameter of the connection pipes.
g) material of manufacture: steel, aluminium, copper and cast-iron radiators. Steel radiators are characterized by a low water capacity, which allows for quick heating of the apartment and can be of various sizes and forms, thanks to which they fill the space in the rooms very well,
h) standard equipment of the radiator,
i) manufacturer's warranty period. The warranty confirming the quality of the products can be provided by both the seller and the manufacturer of the device. From the customer's point of view, a warranty obtained from the manufacturer is a better solution. This is because it allows to gain additional information on the purpose of the radiators with highlighted cases when the warranty does not apply. This prevents arbitrary interpretation of the records. The way the radiators are installed in the installation and their operation has an important influence on obtaining the warranty.

Different manufacturers have different markings on the use of heaters. Some of the manufacturers have precisely defined requirements for which buildings the radiators are intended for, in other cases it is defined very vaguely.

3.2 Usability evaluation criteria

These criteria influence installation and operating costs. They also affect the cost of interior design:
a) ease of installation of the radiator,
b) resistance to heating medium pressure,
c) durability of the radiator (corrosion resistance) and durability of the paint finish,
d) the impact resistance of the heater,
e) aesthetic appearance.

3.3 Hygiene criteria

For rooms with increased hygienic requirements (hospital and operating rooms, food and pharmaceutical industry plants, etc.), hygienic radiators are used. The following criteria can be indicated here:
a) the way heat is transferred to the environment,
b) shape of the radiator surface and ease of washing and cleaning radiators,
c) radiator surface temperature, too high surface temperature of the radiator causes dust to scorch.

4. ASSESSMENT OF RADIATORS USED IN BUILDINGS

The algorithm for technical and economic assessing radiators is a complex issue as it is influenced by factors assessed individually by each person. These criteria can be objective and subjective.

The objective factors include:

- price,
- the design of the components.

Subjective factors include:

- aesthetics of workmanship,
- quality,
- standard equipment.

In the following article, the following parameters are used as evaluation criteria:

- index Q_M [W/kg],
- index Q_V [kW/m^3],
- index Q_L [W/m].

Criteria **not taken into** account due to quick and easy change:

- guarantee period
- the unit price of the radiator,
- price [W/euro].

The analysis was carried out for convection room heaters of comparable shape and material of construction with water supply in heat output ranges 200, 500, 1000 and 1500 W [8].

Due to the variety of radiator types and the volume of the following study, the analysis has been narrowed down to the simplest and most common solutions found in residential buildings. The focus has been on radiators with side feed in a height of approximately 600 mm and the average surface temperature of the radiator 70°C (t_z/t_p= 75/65 °C). Bathroom radiators were also taken into account during the analysis.

The following work analyses the radiators available on the market from the following companies:

- PURMO [7, 8],
- Eurotherm [9],
- InstalProjekt [10],
- Buderus [11],
- ECA [12],
- Alplast [13],
- Rayco [14],
- Armatura Kraków [15]
- Korado [16].

It must be emphasised that the data on the radiators are declared by the manufacturers or their representatives [17]. Some data is very difficult to verify and sometimes not available at all. Test protocols confirming the declared parameters are missing. The most important documents regulating the rules for placing radiators on the market are:

- Regulation (EU) No. 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC.
- Commission Delegated Regulation (EU) No. 568/2014 of 18 February 2014 amending Annex V to Regulation (EU) No. 305/2011 of the European Parliament and of the Council concerning the assessment and verification of constancy of performance of construction products.
- PN-EN 442-1:2015-02 Radiators and convectors. Part 1: Technical specifications and requirements
- PN-EN 442-2:2015-02 Radiators and convectors. Part 2: Test methods and rating.

The most important marking is the mark confirming the admission of a given product to the market and use in the construction industry, as well as compliance with the European harmonized standard or European technical approval.
In EU countries, this is the CE mark. The CE marking is not a certificate of the radiator. It only means a declaration of compliance with Annex ZA to PN-EN 442-1:2015-02 and that it has been subjected to the procedure of assessing the performance properties. The use of such a marking is the responsibility of the manufacturer.
The label must also contain information containing the number and date when the declaration of conformity was issued. It is also important to indicate the document on the basis of which the manufacturer had the right to issue a declaration. Each radiator has its own label with a marking system.

5. RESULTS

The results of selected parameters are presented below in tabular form (Table 1). These parameters are appropriately sorted according to the heat output of the radiator. These parameters make it easy to select the radiator you are interested in and to evaluate it against other solutions.

Table 1. The results of the compared parameters Q_M, Q_V, Q_L

Producer	Thermal power [W]	200			500			1000			1500		
	Radiator /index	Q_M W/kg	Q_V kW/m³	Q_L W/m	Q_M W/kg	Q_V kW/m³	Q_L W/m	Q_M W/kg	Q_V kW/m³	Q_L W/m	Q_M W/kg	Q_V kW/m³	Q_L W/m
PURMO	C11				52,4	333	1000	52,4	333	1000	49,1	313	1000
	C21s				43,4	202	1250	43,4	202	1250	43,4	202	1250
	C22					269		50,7	269	1709	50,7	269	1709
	H10	39,7	167	500	49,6	208	625	49,6	208	625	45,8	192	577
	H20				40,2	161	1000	40,2	161	1000	43,0	173	1071
	Santorini				54,4	118		54,9	118				
EUROTHERM	EC11				48,1		833,3	52,4		909	48,1		833
	EC21				42,8		1250	42,8		1250	42,8		1250
	EC22							51,4		1667	49,3		1667
	EX500	61,4	222	1000	76,7	278	1250	76,7	278	1250	76,7	278	1250
INSTAL-PR.	TU2	50	76,9	860	38,5	74	826,4	40	77	860			
	TU3	29,4	59,5	1075	32,7	66,1	1195	34,6	70,03	1262	35,3	71,4	1290
	TU4	33,2	65,4	1434	35,5	70,0	1536	38,3	75,41	1654	37,3	73,5	1612,9
	GŁ-ST.	44,4	98,0		48,5	93,8		56,8	108				
BUDERUS	K-Pr 10				46	164,5	625	46	164,5	625	46	164,5	625
	K-Pr 11				43	219,3	833	46,9	239,2	909,09	48,3	246,7	937,5
	K-Pr 20				43	219,3	833	46,9	239,2	909,09	48,32	246,71	937,5
	K-Pr 21				40,6	171,2	1250	40,6	171,2	1250	40,58	171,23	1250
	K-Pr 22							45,4	228,3	1666,7	45,41	228,31	1666,7
	K-Pl 10				38,6	328,95	625	38,6	329	625	38,58	328,95	625
	K-Pl 11				38,4	438,59	833	41,9	478,5	909,09	40,66	464,39	882,38
	K-Pl 20				36,8	175,44	1000	36,8	175,4	1000	36,8	175,4	1000
	K-Pl 21				38,8	227,27	1250	38,8	227,3	1250	38,8	227,3	1250
	K-Pl 22							36,1	250,6	1428,6	37,9	263,2	1500
ECA	11 PK				46,8	268,82	833,3	51,1	293,2	909,01	52,7	302,4	937,5
	21 PKP				41,2	201,61	1250	41,2	201,6	1250	41,2	201,6	1250
	22 PKKP							47	268,8	1666,7	47	268,8	1666,7
ALPLAST	A St.	47,6	111		55	121,95		58,1	137				
	A Cu	54,1	125		69,4	172,4		74,1	175,4				
RAYCO	RAYCO NE				85	250	1562	85	250	1562,2	85	250	1562,2
	RAYCO RD				84,5	245,0	1562	84,5	245	1562,2	84,5	245	1562,2
	GAVIA				84,5	245,0	1562	84,5	245	1562,2	84,5	245	1562,2
	CHOPIN				84,5	245,0	1562	84,5	245	1562,2	84,5	245	1562,2
	MANGO				77,2	255,1	1562	77,2	255,1	1562,2	77,2	255,1	1562,2
A. K.	G500F	66,7	333	1250	66,7	333,3	1250	74,1	370,4	1388,9	71,4	357,1	1339,3

KORADO	11 VK				53.2	322.6	1000	53.2	322.6	1000	53.2	322.6	1000
	21 VK				39.4	179.3	1040	48.8	222.1	1288	54.9	250.0	1450
	22 VK							65.3	289.3	1678	65.3	289.3	1678
	10 Hygiene	31.3	161.3	500	31.3	161.3	500	31.3	161.3	500	31.3	161.3	500
	20S Hygiene				34.2	163.8	950	33.8	162.1	940	33.8	162.1	940

6. SUMMARY OF TECHNICAL ANALYSIS OF RADIATORS

As a result of the parameters presented, the status of the radiator assessments is as follows:

1) Due to the Q_M parameter, the highest values of approx. 80 W/kg have aluminium radiators from companies: „Eurotherm" – Excellent 500, „RAYCO" – RAYCO NE, RAYCO RD, GAVIA, CHOPIN, MANGO and „Armatura Kraków" – G500. For their almost twice as lightweight construction compared to tubular steel radiators Tubus type of the "INSTAL-PROJEKT" company whose Q_M rate is around 35W/kg. Slightly worse values for the Q_M parameter of about 70 W/kg have copper radiators from the company "Alplast".
2) With regard to the Q_V parameter, we distinguish between single panel steel radiators type K-Plan 11 by „Buderus" with a Q_V of approximately 450 W/dm^3,
3) The weakest Q_V rating is for Tubus tubular steel radiators from "INSTAL-PROJEKT" with a Q_V of approximately 60 W/dm3.
4) the highest values 1709 W/m of the Q_L parameter have double-ribbed steel panel radiators type C 22. Radiators EC 22, K Profil 22, 22PKKP approx. 1670 W/m, tubular steel radiator type TUBUS 4 with a Q_L of approx. 1600 W/m and aluminium radiators type RAYCO NE, RAYCO RD, GAVIA, CHOPIN, MANGO and G500F with an index of approximately 1600 W/m to their compact design in relation to the other radiators analysed (large values of the Q_L parameter are influenced by the depth of the radiator construction).

In the article above, different solutions for heating flats are presented, the focus was on water-fed radiator solutions. After detailed analysis, the evaluation criteria selected were Q_M, Q_V, Q_L and presented the results of the work. However, in each case the nominal power Q_N is declared by the manufacturer so it is not easy to check so it should be tested.

As expected, aluminium radiators have the highest heat output to material mass Q_M, Q_V - single panel finned steel radiators. Q_L double-ribbed steel radiators, on the other hand, thanks to their compactness (construction depth of the radiator). However, the matter of choosing radiators is individual by each user and the following requirements as to the heater should be taken into account:

– should be optically adapted to the room,
– in order to exclude the risk of injury, they should not have sharp edges,
– heat transfer should be regulated,
– should be easy to clean,
– should be small in size as far as possible, while still providing intensive heat exchange,
– the water volume and weight of the radiator should be as low as possible,
– should have high corrosion resistance,
– installation should be quick and easy to assemble,
– radiators should not be expensive.

ADDITIONAL INFORMATION

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