Carmen MÂRZA, Georgiana CORSIUC, Ana Maria GRAUR

STUDY REGARDING THE GEOMETRY OF SOME PIECES USED IN FLAT-OVAL DUCTS

Abstract: *Nowadays people spend increasingly more time indoors, which has led to higher expectations in terms of comfort and indoor air quality. In this respect, an important role belongs to the ventilation and air conditioning systems, which transport fresh or respectively, treated air. The agent is transported by means of large dimensions tubes, having circular, rectangular and more recently flat oval sections. From technical point of view, the flat-oval sections combine the advantages of the circular and rectangular types. Flat-oval tubes are less widespread in our country, which is the reason why the authors consider important to study the parts necessary for the tubing, such as various fittings and transition pieces. A complete study of these parts requires both fluid flow and geometric analysis. This paper presents geometrical solving of some pieces used for changing the flow direction such as elbows, branches or bifurcations. These parts, if are not suitable selected, can introduce local load losses, having as possible disadvantages increased energy costs and low reliability. Solving these pieces requires knowledge of descriptive geometry regarding cylindrical and conical surfaces, namely, plane sections, developments and intersections between cylinders.*

Key words: *applied geometry; cylindrical surfaces; flat-oval ducts; elbows; branches.*

1. INTRODUCTION

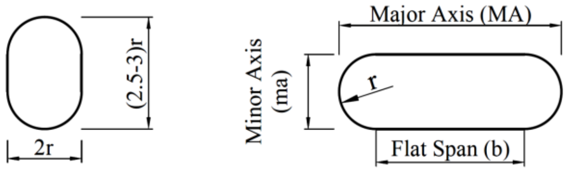
The pipes used in the field of building services have in most cases, as it is known, circular sections. When transporting large fluid flows, which involve large sections, depending on the possibilities of installing the pipes, apparent, buried or concealed in technical spaces, there was a need to find other types of sections.

For example, in the case of wastewater ducts, the use of cross-sections as perfect oval, ovoid or other technical curves composed from circle arches was allowed. Another type of section is the flat-oval type - with various ratios between the circular area and the flat area. In fact, some cross-sections of this type have been standardized in Germany, and then in our country. They are mounted upright - Figure 1.a, so that the pressure of the earth on the walls of the pipes is favourable and the risk of depositing impurities on the bottom of the pipes is minimal, to avoid their rapid clogging.

With the development of the occupational hygiene concept at the beginning of the 20th century, the ventilation/air conditioning installations began to be used on a large scale in buildings with different destinations: industrial, administrative, commercial. Even in residential buildings, located in hot and/or humid climatic areas, this type of installations are used. Moreover, the contemporary man, sensitive to the micro-climate, demands working and living conditions that meet the imposed parameters by the thermal comfort. In many situations, the technical solutions of the specialists recommend complementary installations of heating, cooling, air conditioning, ventilation with the possibility of recovering energy from the extracted air. The ventilation/air conditioning installations use air as thermal agent and require sections of pipes with a wide range, respectively about 100…2000 mm. Thus, the shape of the cross-section used can be circular, rectangular and flat-oval. The last one combines the advantages of the circular or rectangular types, among which, one can mention: the reduced height of the section for the same area compared to the circular sections, respectively, low pressure losses and reduced risk of depositing impurities compared to the rectangular sections [1]. As a rule, they are mounted in the position indicated in Figure 1.b. In this regard, ASHRAE Advanced Energy Design Guides recommend the use of flat-oval pipes instead of rectangular ones, when the height is limited. Among the advantages of flat-oval sections, we mention that for the same section, thus implicitly the same air flow rate, it requires significantly reduced installing heights compared to the circular section tube, which leads to more efficient use of the space. Consequently, for the same useful section results a decrease in the height of the tubing, inclusively of the technical space, between 50 and 88 % [2].

The following notations were used:

r = radius of the circular portion of the flat-oval pipe
b = flat span length (b= MA-ma);
MA = length of major axis (MA = b+2r);
ma = length of minor axis (ma = 2r).



(a) (b)

Figure 1 Mounting positions of flat-oval pipes.

The flat-oval tubing can be made from galvanized sheet processed and joined longitudinally. Another method consists in processing circular spiral tubing in special machines where the pressing takes place, respectively the stretching until the desired shape of the cross-section is obtained. The execution technology is chosen according to the type of agent transported through the channels. The tubes with spiral folding and the related fittings are executed on computer numerical control (CNC) machines.

The use of rubber gaskets gives the tubes a very good sealing.

In accordance with ASHRAE recommendations, most commonly circular tubes are used, and in the areas where the installation height does not allow their use, the transition to the flat-oval section is made, returning then to the circular section [3]. Therefore, it is necessary to use some fittings, which will allow to follow the route required for the distribution of the fresh/treated air, respectively the evacuation of the polluted air. For this reason, most comparative analyzes presented by the authors will refer to the circular and flat-oval sections.

In a previous paper, the authors studied the geometry of the transition parts between circular and flat-oval, rectangular and flat-oval or between flat-oval of different sections, following in this paper to deal with the pieces that change the transport direction in flat-oval ducts.

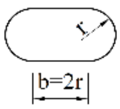
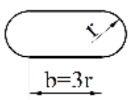
2. PHYSICAL MEASUREMENTS REGARDING FLUID FLOW CALCULATIONS IN FLAT-OVAL DUCTS

2.1 Ducts cross-section

An important size in the various sizing calculations of ducts is represented by the cross-section area. If we make a comparative analysis between the geometry of the circular ducts and the flat-oval ones, knowing that the perimeter remains constant, according to elementary algebraic calculations result cross-section areas specified in Table 1 [4].

Table 1

Geometric dimensions of different cross-section

Cross-section	Perimeter	Radius	Area	Percent
	2πR	R	$\pi \cdot R^2$	100%
	2r(π+2)	0.61·R	$2.65 \cdot R^2$	84%
	2r(π+3)	0.51·R	$2.37 \cdot R^2$	75%

One notice that with the elongation of the circular section, the effective flow section of the fluid is reduced. However, where the mounting height does not allow the installation of the circular ducts, the flat-oval sections are used.

2.2 Equivalent diameter

Usually, for design purposes (friction loss calculations), it is necessary to "convert" rectangular or flat oval ducts to round ducts. This substitution is possible by the means of the equivalent diameter.

By definition, the equivalent diameter (D_{eq}) is the diameter of a circular duct that will give the same pressure drop at the same air flow as the flat oval duct [5], [6].

In the technical literature, to convert flat oval ducts to and from round cross-sections the following equation is given [7], [8]:

$$D_{eq} = \frac{1.55 \cdot A^{0.625}}{P^{0.250}} \tag{1}$$

where:
A – cross-section of the flat-oval duct;
P – perimeter of the flat-oval duct.

The cross section, respectively the perimeter are calculated using the following formulas:

$$A = \pi \cdot r^2 + ma(MA - ma) \tag{2}$$
$$P = 2 \cdot \pi \cdot r + 2(MA - ma) \tag{3}$$

where MA, ma and r were previously defined.

For example, a flat oval duct having MA=320 mm and ma= 76 mm is equivalent to a Ø 160 mm round duct.

2.3 Pressure losses

The pressure losses on a path are composed of linear and local losses. In the case of fittings that change direction, are of interest the local losses that are introduced. These can be quantified in two ways:

a) By means of a local coefficient, called K factor, the pressure loss is calculated using the equation [7], [9]:

$$\Delta p = K \cdot (\rho \cdot V^2)/2 \tag{4}$$

where:
Δp- dynamic pressure losses [Pa];
K - non-dimensional coefficient for local losses;
ρ - air density [kg/m^3];
V - air velocity [m/s].

Every fitting has its own K factor, which is measured experimentally and reported by the fitting manufacturers. Design handbooks are presenting those coefficients in the form of tables or nomographs. More recently, engineers may search for K factors in a very specialized database, the ASHRAE Duct Fitting Database Program. It is a menu-driven database, including loss coefficient values for more than 200 round, rectangular and flat oval fittings. As input, fitting type, geometry and flow rate are necessary. Pictorial outlines of each fitting are included in documentation and may be displayed on screen [10]. Unfortunately, it is not a free application.

b) Often for simplicity in evaluating the local pressure losses, an "equivalent length" method -is used [5]. It is like a replacement of a local loss with a friction loss, when a fitting such as an elbow is assigned a number that represents a length of a straight duct that has an equal pressure drop. For example, a 90^o elbow might have an equivalent length of 4.5 m [11]. This additional length is then added to the straight length of the duct to obtain the total design length [5].

3.THE GEOMETRY OF SOME FITTINGS USED TO CHANGE THE DIRECTION FOR FLAT-OVAL DUCTS

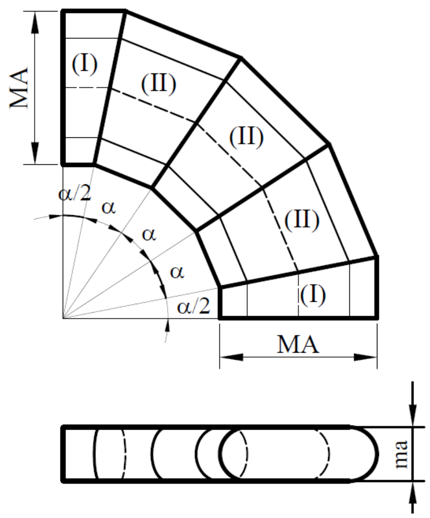
On the route of the ventilation/conditioning ducts having a flat-oval section it is necessary to provide parts for changing the direction such as elbows and different types of branches.

3.1 Elbows

Regarding elbows, these can be of two types [12]:

- Hard bend - if the axis of the piece is contained in a horizontal plane - Figure 2;
- Easy bend - if the axis of the piece is contained in a frontal or profile plane - Figure 5.

In Figure 2.a a hard bend type elbow is represented in double projection and in Figure 2.b it is represented in axonometry. The given solution represents a 90^o elbow consisting of five segments: two equal end segments (noted I), having the angle between the limiting vertical projecting planes of 11.25^o and three identical intermediary segments (noted II), having a 22.5^o angle between the limiting planes [13].



a.

b.

Figure 2 Hard bend elbow.

In the Figures 3 and 4 the developments of the two types of segments were represented, including the true size of the sections composed of flat areas and elliptical parts [14]. The elliptical area is similar to the circular cross-section as the angle between the vertical projecting planes is lower.

Figure 5 represents an easy bend type elbow, respectively in Figure 5.a the double projection, in Figure 5.b the axonometry and in Figures 6 and 7 the developments of the two types of segments which compose the elbow. The geometric solution is similar to the previous case.

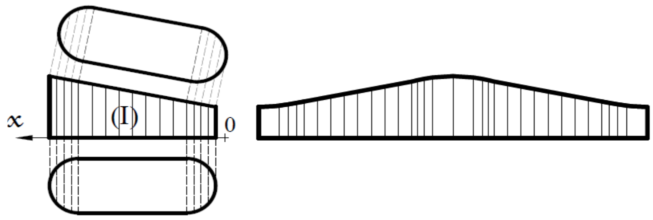


Figure 3 The double projection and development of type I segment.

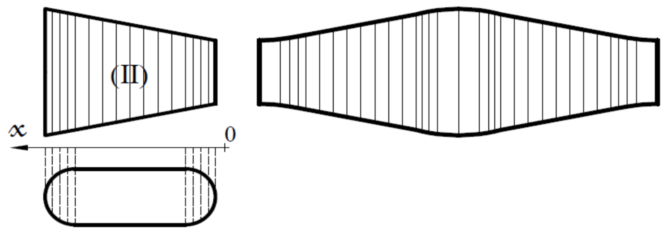
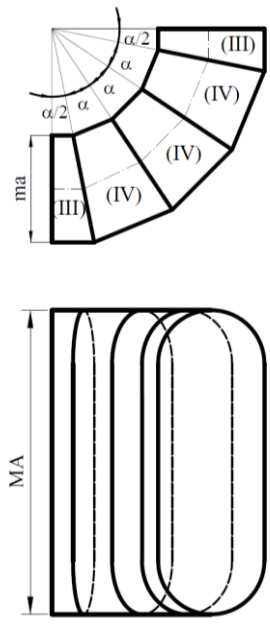


Figure 4 The double projection and development of type II segment.



a.

b.

Figure 5 Easy bend elbow.

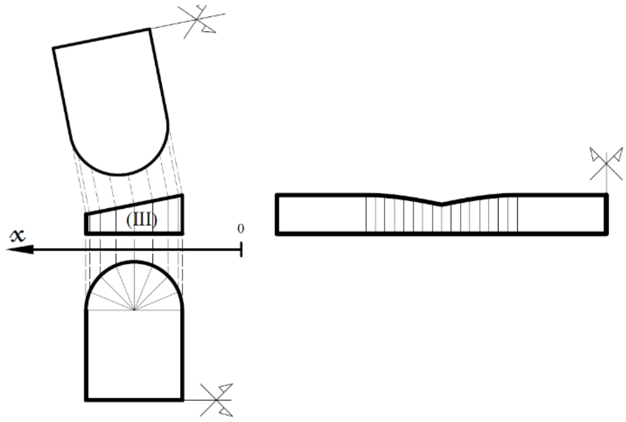


Figure 6 The double projection and development of type III segment.

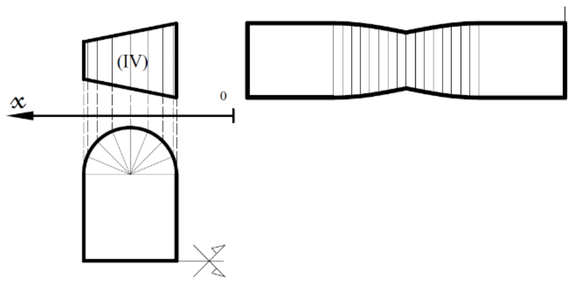


Figure 7 The double projection and development of type IV segment.

3.2 „T" Branches

If the design requires the existence of several sectors to ensure the inlet or outlet of the air through uniformly distributed jets in a large space, it is necessary for the tubing route to branch in several directions.

Thus, the most often used branches are the tees that make 90^{o} between the axes of the cross-sections. Depending on the pipeline route, lateral branches can be used, having the angles between the axes of the cross-sections with different values, the most common being 30^{o}, 45^{o} or 60^{o}.

3.2.1 „T" branches with perpendicular axes

In Figure 8.a, a tee branch, with perpendicular axes, was represented in orthogonal projection on three planes of projection [4]. Due to the fact that, usually, the air flows carried on the secondary section are smaller, the geometric solution is selected so that the minor axis of the secondary section to be equal to that of the main section, changing as needed only the major axis. This solution is advantageous from a geometrical and technical point of view. In this way, the intersection curve between the two duct segments will be composed of flat and curve lines, with the mention that in the vertical projection the intersection curve is projected, in this case, about straight lines.

In Figures 8.b and 8.c were represented the developments of the two parts of the tee branch and in Figure 8.d the piece is represented in 3D.

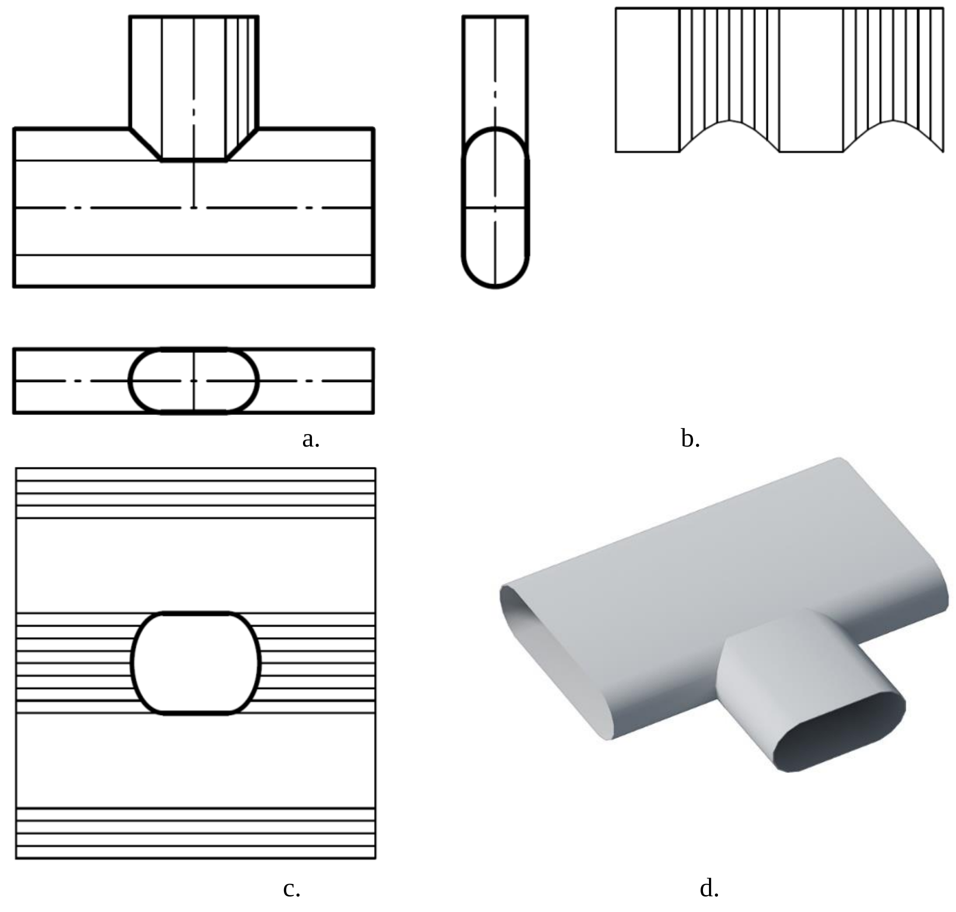
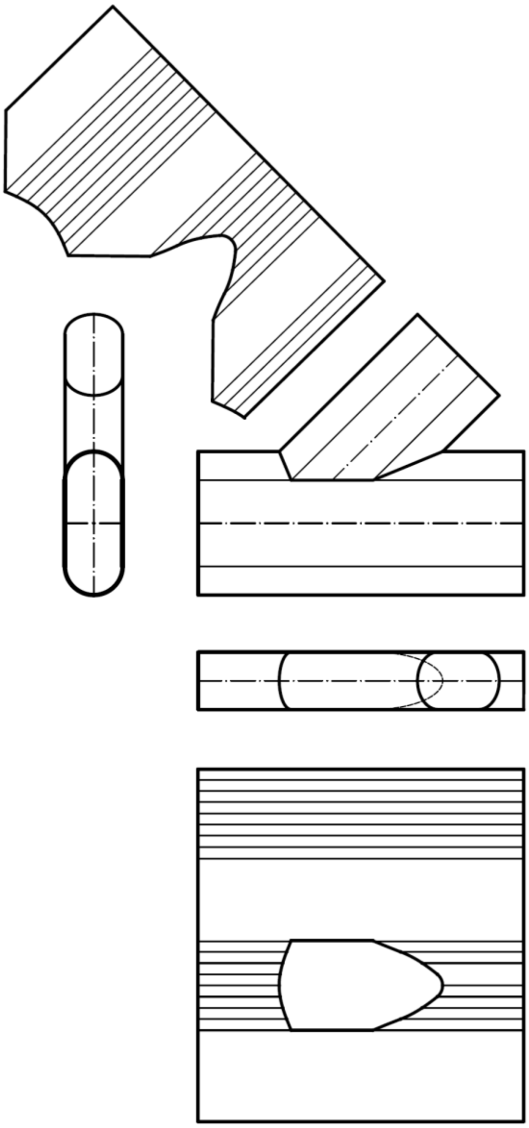


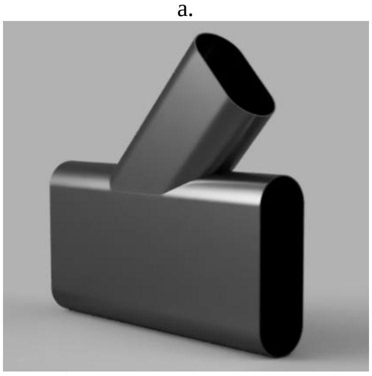
Figure 8 „T" branch with perpendicular axes.

3.2.2 „T” branches with oblique axes

Figure 9 shows a „T” branch with an angle of 45 degrees between the axes, as it follows: Figure 9.a - the triple orthogonal projection and the developments of the two component parts of the piece, Figure 9.b - the 3D representation.



a.



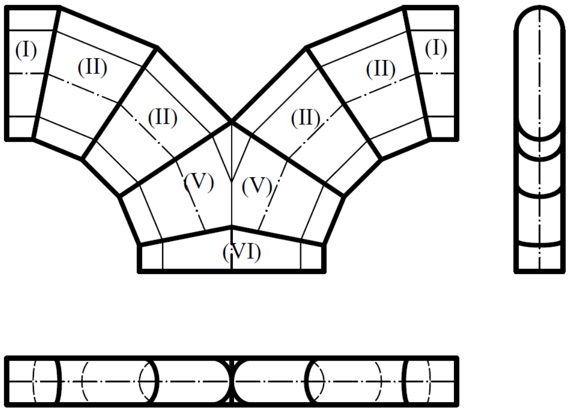
b.

Figure 9 „T” branch with oblique axes.

To obtain the intersection curve between the circular areas of the duct, the sphere as auxiliary surface was used. The most common solution require that the small axes of the sections of the flat-oval channels are equal.

3.3 „Y” Branches

In Figure 10 an „Y” branch is represented, used when the main pipeline route divides in two directions [15]. Usually, the secondary sectors transport reduced air flows. The piece was represented in orthogonal projection on three planes (Figure 10.a), respectively in 3D representation (Figure 10.b). It was selected the solution consisting in four types of segments, respectively type I and II used at the hard bend elbow and two other types of segments noted V and VI, whose developments are represented in Figures 11 and 12.



a.

b.

Figure 10 “Y” branch.

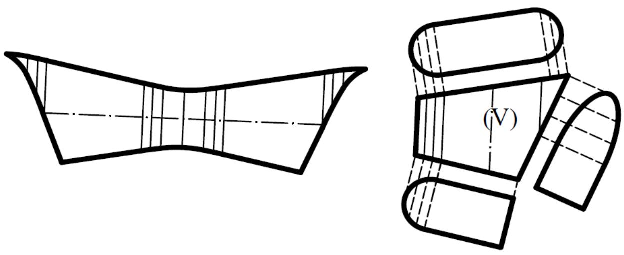


Figure 11 The representation and development of type V segment.

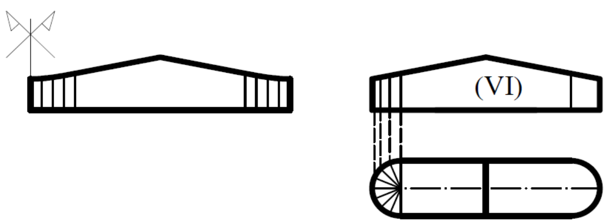


Figure 12 The double projection and development of type VI segment.

4. CONCLUSIONS

The authors considered important to study the flat-oval channels and the corresponding fittings, since in Romania and even in Europe these were not widely implemented. These types of ducts were introduced in the design handbooks of the last years without carrying out a hydraulic and geometric study of them. For this reason, these have not been implemented either, as it happened in countries from America and Asia, which recommend and use them due to the advantages offered. Of course, their construction, which is carried out on computer numerical control machines, prior involve a more elaborate geometric study, which requires the application of some knowledge of descriptive and surface geometry, especially in fittings manufacturing.

The solutions presented in the paper are not unique. The fittings can be composed of more or less segments, having different angles, depending on the situation imposed by the route of the duct. When selecting the proposed solution, consideration was given to ensure an air flow with reduced turbulences. At the same time, by repeating some modules, for the same cross-section of the duct, it ensures increased efficiency and flexibility in production.

REFERENCES

[1] Mârza C., Deac, A., Corsiuc G, (2015). *Methods for representing the tubing of ventilation/air-conditioning plants*, Journal of Industrial Design and Engineering Graphics, Volume 10, Special Issue ICEGD, fascicle 2, June 2015, pp. 31-36.

[2] Mârza, C., Corsiuc, G., Graur, A. M. (2019). *About the geometry of transition pieces relative to the flat-oval tubing.* FME Transactions, Vol. 47, No. 2, pp. 337-342.

[3] ASHRAE, 2011. Advanced Energy Design Guides, available online at: http://www.arch.ttu.edu/people/faculty/hill_g/DesignStudioResources/AEDG50-SmallMedOfficeBldgs_2011.pdf. *Accessed*: 2021-12-14.

[4] Mârza, C., Corsiuc, G., Graur, A.M. (2020). *About the geometry of some FITTINGS used in flat-oval ducts*, 7th International Scientific Conference on Geometry and Graphics moNGometrija 2020, 18th - 21st September 2020, Belgrade, Serbia

[5] Bhatia, A. HVAC - *How to Size and Design Ducts*, Course No: M06-032, Continuing Education and Development, Inc., Available online at: https://www.cedengineering.com/userfiles/How%20to%20Size%20and%20Design%20Ducts.pdf. *Accessed*: 2021-12-14.

[6] Koch, P., (2008). *Equivalent diameters of rectangular and oval ducts*, Building Services Engineering Research and Technology; 29(4):341-347. doi:10.1177/0143624408094631

[7] Heyt, J. W., Diaz, M. J. (1975). *Pressure drop in flat oval spiral air duct.* ASHRAE Transactions, pp. 221–232.

[8] ASHRAE, (1989). Handbook: Fundamentals, American Society of Heating, Refrigeration and Air-conditioning Engineers.

[9] Smith, Shaun J. (1998). *Determination of k-factors of HVAC system components using measurement and CFD modelling*. PhD thesis, University of Nottingham. http://eprints.nottingham.ac.uk/11059/

[10] Duct System Design Guide, (2003). First Edition, McGill AirFlow Corporation, Groveport, Ohio.

[11] TECA Oval Fitting Summary, Thermal Environmental Comfort Association, Available online at: http://eccomfg.com/pdf/News/OVAL%20FITTING%20STUDY_rev3.pdf. *Accessed*: 2022-02-01.

[12] SPOT, (2017). Single-Wall Flat Oval Fittings, Spiral Pipe of Texas, Available online at: *https://www.spotusa.com/wp-content/uploads/2017/05/Flat-Oval-Terms.pdf*. *Accessed*: 2022-01-18.

[13] Mârza, C., Corsiuc, G. (2016). *Study regarding the geometry of some connecting pieces for circular ducts* in: Proceedings of the 5th International Scientific Conference on Geometry and Graphics moNGeometrija 2016, Belgrade, Serbia. pp. 403-409.

[14] Moncea, J., Alămoreanu, I. (1975). *Development of surfaces (Desfășurarea suprafețelor)*, Ed. Tehnică, Bucharest, Romania.

[15] ***https://itsolution.lindab.com/LindabWebProductsDoc/PDF/Documentation/ADS/it/Technical/Lindab%20Oval.pdf. *Accessed*: 2022-01-18.

Authors:

Assoc. Prof. Ph.D. Eng. Carmen MÂRZA, Director of Department, Technical University of Cluj-Napoca, Department of Building Services, E-mail: Carmen.Marza@insta.utcluj.ro

Lecturer Ph.D. Eng. Georgiana CORSIUC, Technical University of Cluj-Napoca, Department of Building Services, E-mail: Georgiana@mail.utcluj.ro

Lecturer Ph.D. Arh. Ana-Maria GRAUR, Technical University of Cluj-Napoca, Faculty of Architecture and Urban Planning, E-mail: arh.anamariarusu@gmail.com