Comparison of the Standard of Air Leakage in Current Metal Duct Systems in the World

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Abstract. Based on the requirements of air leakage of metal ducts in Chinese design standards, technical measures and construction standards, this paper compares the development history, the classification of air pressure levels and the air tightness levels of air leakage standards of current Chinese and international metal ducts, sums up the differences, finds shortage by investigating the design and construction status and access to information, and makes recommendations, hoping to help the majority of engineering and technical personnel.

1. Prefaces
The amount of air leakage refers to the amount of air that leaks or infiltrates into the duct system at a certain static pressure through the duct body structure and its interface within a unit of time. The amount of air leakage in the air duct is an important indicator of the ventilation and air conditioning system engineering and energy consumption reduction. The study on the typical allowable air leakage standards at home and abroad helps to better serve the international market, improve the quality of projects and promote the development of enterprises.

2. The Air Leakage Standards for Metal Ventilation Pipes in China

2.1. Requirements for Air Leakage in Design Codes and Technical Measures
The current 2009 version of "Technical Measures for Design of Civil Construction: Heating, Ventilation and Air Conditioning" 4.6.1 proposed "ventilation system fan ventilation should be attached to air duct and equipment air leakage based on the calculation of air volume in the system. General ventilation, air-conditioning air leakage additional constants may take 5%~10%, smoke extraction system may take 10%~20%[1]."

According to GB50736-2012"Design code for heating ventilation and air conditioning of civil buildings"6.5.1, the fan selection should be based on the pipeline characteristics curve and the fan performance curve. The leakage air of duct and equipment should be attached to the fan air volume, air supply and exhaust system can be added 5% ~10%, smoke exhaust and air exhaust system should be attached 10%~20%[2].

According to GB50019-2015"Design code for heating ventilation and air conditioning of industrial building" 6.7.4, the amount of air leakage in the system should be controlled by the selection of the duct material and the process of duct making, and the air leakage rate of the system should meet the requirements: the non-dust-removal system should not exceed 5% and the dust-removal system should not exceed 3% [3].
According to JGJ/T141-2017 "Technical specification of air duct" 5.1.1, air duct leakage and allowed air leakage class shall meet the requirements in Table 5.1.1, and the air leakage class of the air duct shall be divided into five class of A, B, C, D and E and indicate: 1) The maximum allowable air leakage of medium-pressure duct shall not be greater than Class B, the maximum allowable air leakage of high-pressure duct shall not be greater than Class C, and the duct of special requirements shall not be greater than Class D. 2) The amount of air leakage in the exhaust, dust and low temperature air supply systems shall not exceed Class B; 3) The amount of air leakage of 1 to 5 purification air-conditioning system should not exceed Class C; 4) Class E only for virology laboratory and other special purpose duct [4].

2.2. Construction Acceptance Norms on the Amount of Air Leakage

GB50243-2002 "code of acceptance for construction quality of ventilation air conditioning works" 4.2.5 replaced the 1997 version standard on April 1, 2002, the standard for rectangular duct leakage was specified in the form of a formula, as shown in table 2. And for low pressure, medium pressure round metal duct, composite duct and the use of non-flanged non-metallic duct allowed air leakage was required 50% of rectangular duct prescribed value [5].

| Duct category       | Allow air leakage [m³/(h·m²)] |
|---------------------|--------------------------------|
| Low pressure duct   | Q≤0.1056 P⁰.⁶⁵                 |
| Medium pressure duct| Q_m≤0.0352 P⁰.⁶⁵                |
| High-pressure duct  | Q_h≤0.0117 P⁰.⁶⁵                |

GB50591-2010 "Code for construction and acceptance of clean room" on the allowable air leakage standards consistent with the requirements of GB50243-2002. However, in 5.2.12, "for duct processing and installation tightness of the test pressure, the main pipe can be used 1500Pa, trunk (including branch-trunk) can be used 1000Pa, branch can be 700Pa, can also be used as the working pressure test pressure" [6].

GB50243-2016 "code of acceptance for construction quality of ventilation air conditioning works" on July 1, 2017 came into effect as the current effective standards. Compared with the 2002 version, there are two changes in the allowable air leakage. The first is that the working pressure of the air duct system is divided into three categories: low pressure, medium pressure and high pressure. The low pressure section is divided by ± 125Pa and less than or equal to 125Padmin divided into micro-pressure, formation of micro-pressure, low pressure, medium pressure and high pressure four categories. The second is to use the air leakage test instead of the light leakage test [7].

3. The Metal Ventilation Pipe Allowed Air Leakage Standards in Foreign Countries

The Swedish WS AMA 1966 is the first national standard to classify the air duct tightness into A and B class and compulsory inspection. The air tightness of the spiral circular duct is much better than the rectangular duct [8]. Later in the 1980s, other developed countries also established duct air tightness standards.

In 1996, European countries unified the standard of air leakage of air duct system to EUROVENT2/2[9]. The air duct tightness was divided into four class of A, B, C and D. The current air duct leakage of the latest standards are DIN EN 12237-2003[10] and DIN EN 1507-2006[11]. DIN EN 1507-2006 is published by the German Institute of Standardization (DIN) and is implemented jointly by most current European countries.

The current American standard for detection of air leakage in ventilation ducts of civil buildings is ANSI/SMACNA 016-2012[12]. This standard started in 1966 and has been updated with the continuous improvement of the ventilation technology and ventilation requirements, and up to now, it is the latest implementation standards for US civil buildings duct system.

The current air leakage standard in the United Kingdom is based on DW/143, which was published by the British Association of Heating, Ventilation and Air Conditioning first edition in 1983, second
edition in 1986, third edition in 1991, fourth edition in 1994, fifth edition in 2000, which is the current British typical air leakage testing standards [13].

4. Comparison of International Current Air Duct Leakage Standards
In different countries and regions, the criteria for the determination of air leakage in the air duct system are similar, and they are determined by the method of classifying the pressure grade of the air duct system and the air tightness grade of the air duct. The maximum allowable air leakage of wind pipes of different air tightness grades is different, and the calculation formula of the air leakage in each standard unit is consistent:

\[ q_{LA} = \frac{Q_L}{A} = C \cdot \Delta P_s^n (1) \]

In type: \( q_{LA} \) as air leakage rate of surface area of unit wind pipe, \( m^3/(m^2\cdot h) \); \( Q_L \) as the air leakage measured by the instrument, \( m^3/h \); \( A \) is surface area of wind pipes, \( m^2 \); \( C \) as the air leakage constant, and the air tightness class of the air duct is usually determined by it; \( \Delta P \) as the static pressure difference inside and outside the surface of the wind pipe, Pa; \( n \) as air leakage index, It is related to the flow state of the leaking path, usually 0.65. Therefore, most of the difference of the maximum allowable air leakage in these typical air leakage standards is caused by the difference of the air leakage constant.

The air tightness grade of Chinese ventilation pipelines is divided into four grades. Detection of air leakage by using the sense method for micro pressure and the relationship between the air leakage constant of three grades of low pressure, medium pressure and high pressure is 3 times. The air tightness grade of the European Union ventilation pipeline is divided into four grades, D class is special gas tightness grade for special pipes, and the relationship between four adjacent air leakage constants is 3 times. The leaking constant of the A, B and C class are compared with the leaking constant of low, middle and high pressure in China is lower about 8%. According to the pipeline type, the air leakage gas tightness of American ventilation pipes are divided into two kinds: the rectangular
pipeline and the circular pipeline. The circular pipeline is divided into three grades, and the rectangular pipeline is divided into four grades, and the adjacent air leakage constant is 2 times; the air leakage of the UK ventilation pipeline is divided into three grades, and consistent with the first three class of the EU. In a word, the air leakage constant of the EU > China > United States.

### Table 3. Current air leakage standard duct tightness Rank comparison.

| Standard                          | Tightness class | Air leakage constant |
|-----------------------------------|-----------------|----------------------|
| China                             | Low pressure    | 0.1056               |
| GB50243-2002                      | Medium pressure | 0.0352               |
|                                   | high pressure   | 0.0117               |
|                                   | Micro-pressure  | ——                   |
| GB50243-2016/JGJ/T141-2017       | Low pressure /A | 0.1056               |
|                                   | Medium pressure /B| 0.0352       |
|                                   | high pressure /C | 0.0117               |
|                                   | A               | 0.0972               |
|                                   | B               | 0.0324               |
|                                   | C               | 0.0108               |
|                                   | D               | 0.0036               |
| EU                                | CL3             | 0.0152               |
| DIN EN- 1507-2006                 | CL6             | 0.0304               |
|                                  | CL12            | 0.0608               |
|                                  | CL6             | 0.0304               |
|                                  | CL12            | 0.0608               |
| US                                | CL24            | 0.1216               |
| SMACNA-2012                       | CL48            | ——                   |
|                                  | A               | 0.0972               |
|                                  | B               | 0.0324               |
|                                  | C               | 0.0108               |
| KA                                 |                |                      |
| DW/143-2002                       |                |                      |

According to the formula (1), the maximum allowable air leakage of the ventilation pipeline under the working pressure of each country can be calculated in the standard of the air leakage of the typical metal duct, and make the maximum allowable air leakage curve of the ventilation ducts in each area. As shown in Figure 1-4, allows the air leakage of shaft unit is m³/h (m²), pressure shaft unit is Pa.

Comparing Fig.1 and Fig.2, Chinese low-pressure / A-level pressure range corresponds to the first small portion of the EU’s A, B and C grades; medium / high-pressure / B-level corresponds to the latter large portion of the EU’s C-grade and the first part of the EU’s D-grade; high-pressure / C-level corresponds to the latter part of the EU’s D-grade, the pressure range of the ducts at all levels China > EU, the maximum allowable air leakage corresponding to the duct pressure level and the air tightness class China > EU.

Comparing Fig.1 and Fig.3, the upper air duct pressure in China and the United States are all 2500pa. The pressure range of Chinese low-pressure / A-level corresponds to the United States CL24 with the same pressure range and the same curve trend. The maximum allowable air leakage China < USA; B-level corresponds to all CL12 grade and the first part of CL6, before 900pa, the two curves the same, 900pa-1500pa, the United States classified as CL6 tightness, but the maximum allowable air leakage China < the United States; China High Pressure / C-Level corresponds to the latter part of the United States CL6, the maximum allowable air leakage China < United States; Overall, the total pressure range of the air tightness of China and the United States is the same pressure range at all levels, the maximum allowable air leakage curve in China than the United States Flat, the maximum allowable air leakage China < the United States, China and other air tightness higher than the United States.
As can be seen from Fig.1 and Fig.4, the maximum allowable air leakage of low pressure / class A, medium pressure / class B and high pressure / class C ducts in Chinese ventilation system corresponds to Class A, Class B and Class C air ducts in UK, the trend of the graph is similar, the maximum allowable air leakage corresponding to the same pressure is similar, the difference of the maximum allowable air leakage of the same pressure is the difference of air leakage constant, and the difference between the maximum allowable air leakage and the air leakage constant is consistent. In summary, the pressure range under the air tightness of the ventilation pipe China > UK, the maximum allowable air leakage under corresponding pressure China > UK.

![Figure 1. Chinese largest allowable ventilation duct ventilation curve](image1)

![Figure 2. EU’s largest allowable ventilation duct ventilation curve.](image2)
In summary, the air tightness class pressure range: the EU=UK<China=US; the pressure range under the various class; the EU<the United States<China; The ensemble maximum allowable air leakage: the EU<China<the United States. The highest level of air tightness in the EU, the lowest in the United States, the middle in China and the United Kingdom and the higher in the United Kingdom over China;

5. Conclusions
Based on the standard of air leakage in metal ducts in China, this paper compares the current international standards of air leakage with respect to the history of development, the classification of pressure levels and the degree of airtightness and put forward some suggestions by means of surveys and access to data and other methods on the current air duct leakage standards and construction operations: to improve the unity of the standards on the air tightness requirements; to enrich the actual project data; to improve the understanding of designers on the amount of air leakage; to increase construction personnel training efforts, hoping to help the majority of engineering and technical personnel.
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