COMPARISON OF GENERAL VENTILATION AIR FILTER TEST STANDARDS BETWEEN AMERICA AND EUROPE

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ABSTRACT

As the world trade field is expanding, international standard of air filter is urgently needed. At present, China is undergone its revising the national standards, therefore, the development of major air filter standards between America and Europe is compared here. Diameter distribution of KCl aerosol used in ASHRAE52.2 is similar with atmospheric dust, but research for test dust representing actual condition is still needed. Concepts for electrostatic discharge between Europe and America are different, and classification upon minimum life efficiency (MLE) is recommended. Final pressure drop in EN 779:2002 should be lowered to reflect reality, and particle rebound phenomena should be included. High efficiency particulate air filter (HEPA) should be installed upstream of tested filter. Measures to test dust holding capacity is recommended to be incorporated in ASHARE 52.2.

KEYWORDS

air filter, test standards, test aerosol, filter classification

INTRODUCTION

Now every country owns respective air filter test standards, which make the selection and comparison of different air filters difficult. Although air filter test standards have been existed for nearly a hundred years, the contactors are always confused for the constantly air filter test standards revising with the development of test instruments. As the world trade field is expanding, international standard of air filter is urgently needed. At present, China is undergone its revising the national standards, therefore, the development of major general ventilation air filter standards, especially between America and Europe, is compared here, from test procedures, aerosol types and its size, air filter classification, to the final pressure drop etc. Some problems existing and future development are proposed here, which may be useful for the revising of new standards.

DEVELOPMENT OF GENERAL VENTILATION AIR FILTER TEST STANDRADS

1.1 America

In 1964, American Air Filter Institute and National Bureau of Standard made standard respectively, and the former tested the arrestance with artificial test dust while the latter used the dust spot efficiency. In 1968, ASHRAE published the unified standard ASHRAE 52-68, which measured the arrestance as well as the dust-spot efficiency with artificial test dust, it was the first formal standard for testing air filters in commercial and industrial HVAC applications, and it was used to guarantee the cleanliness of heat exchanger surface. In 1976, ASHRAE Standard 52-76 was published, and the atmospheric dust-spot efficiency was the difference compared with ASHRAE 52-68. This standard was used to test coarse and fine filters since then, until in 1992 it was displaced by ASHRAE52.1. ASHRAE52.1 was then approved by the American National Standards Institute as a national standard. ASHRAE52.1 was quite efficient for air filters in general ventilation and comfort-driven applications, but was not suitable for

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control of specific contaminants(D.A.Newell 2006), which drove the development of ASHRAE52.2 in 1999. ASHRAE52.2 tests the particle size efficiency and ASHRAE52.1 was continually used to test the efficiency of low-efficiency filter and the arrestance and dust holding capacity of air filters.

Test standards before ASHRAE52.2 only consider the protection of machine and coil, however, as people are more concerned about the indoor air quality and the healthy problem caused by respirable particles, ASHRAE52.2 adopted a Minimum Efficiency Reporting Value (MERV) from particle-removal efficiency corresponding to detailed particle size and worst-case performance over the test term.

Standardized methods in America develops from arrestance—dust-spot efficiency—American particle sizing efficiency, from the original average efficiency to MERV.

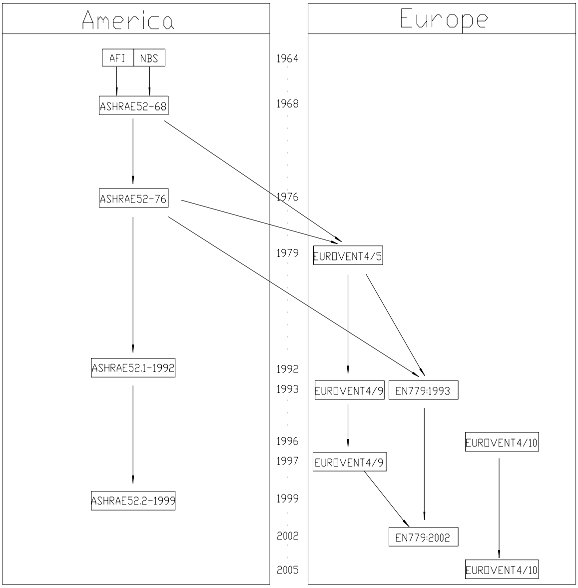

Figure1. Development of standards for air filters in general ventilation.

1.2 Europe

Eurovent 4/5 has been used in Europe since 1979 for coarse and fine filters. It adopted EU1~EU9 classification according to the average dust-spot efficiency and arrestance, but without specified air flow and final pressure drop. In 1993, Eurovent 4/9 was published and later revised in 1997. In this standard Latex or Sebacic acid-bis ester (DEHS) was used as test aerosol, and particle counting efficiency was measured in the size range of 0.2~5μm. Also in 1993, European Committee for Standardization (CEN) published EN 779 which referred to ASHRAE 52-68 and ASHRAE 52-76, but EN 779 didn't include the particle size efficiency either. In order to meet the demand of indoor air quality and environmental protection, and to reflect the actual performance of air filter with the test results, CEN approved EN 779:2002 which referred to EN 779:1993 and Eurovent 4/9:1997. The test rig in EN 779:2002 was the same as in EN 779:1993, and fractional particle efficiency was adopted rather than atmospheric dust-spot efficiency. In order to assure the effectiveness of this replacement, CEN/TC 195/WG1 organized several tests in 4 different labs using atmospheric fractional efficiency during 1993～1994, at the same time dust-spot efficiency was also tested in the reference lab(J.Gustavsson 1996) to find the average efficiency for 0.4μm corresponded to the average dust-spot efficiency. Standardized methods in Europe develop from arrestance—dust-spot efficiency—European particle sizing efficiency, from the original average efficiency to the average 0.4μm particle size efficiency.

COMPARISON AND PROBLEMS

In the following, current ASHRAE52.1, ASHRAE52.2 and EN 779:2002 are compared and illustrated.

Table 1. Comparison of ASHRAE52.1, ASHRAE52.2 and EN 779:2002.

	ASHRAE52.1	ASHRAE52.2	EN779:2002
Test Aerosol	ASHRAE Synthetic Test Dust（for dust holding capacity and arrestance）	Polydisperse KCl solid aerosol	ASHRAE Synthetic Test Dust（for dust holding capacity and arrestance）
	Atmospheric dust（for dust-spot efficiency）		0.4μm liquid DEHS（for particle efficiency）
Particle Sizing Range	n/a	0.30～10 μm	0.2～3μm
Sampling Instrument	Dust-spot opacity meter	Optical counter or Aerodynamic particle counter*	Optical counter**
Test Duct	Straight duct	Straight/U shape duct, HEPA filter installed	Straight duct, HEPA filter must be installed at the inlet
Velocity Uniformity Measures	Plat of 40% open area perorated metal at the upstream of tested filters	Mixing orifice and baffle at the upstream and downstream of air filter	Mixing orifice and perforated plate
Inlet Air	Outdoor air (for dust-spot efficiency) , not indoor air	Indoor air or return air	Indoor air or outdoor air
Exhaust Air	Exhaust to the outside or an indoor space completely isolated from the inlet, or recirculated	Exhaust to the outside, indoor, or recirculated	Exhaust to the outside, indoor, or recirculated, air filter is needed when test aerosol is in the exhaust air
Temperature	n/a	10℃～38℃	n/a
Relative Humidity	n/a	20%～65%	＜75％
Pressure	Positive pressure or negative pressure	Positive pressure	Positive pressure or negative pressure
Air Flow Measurement	ASME long-radius flow nozzle	ASME long-radius flow nozzle	Orifice plate, nozzle, venture tube etc.
Air Flow Range	0.5～2.0 m^3/s	0.22～1.4 m^3/s (rated air flow :9000m^3/h)	0.24～1.5 m^3/s (rated air flow: 3400m^3/h)
Qualification Requirement	(1) air velocity uniformity across duct cross; (2) aerosol uniformity across duct cross; (3) aerosol neutralizer; (4) overload test for particle counter; (5) manometer calibration; (6) zero filter efficiency; (7) correlation ratio test; (8) 100% filter efficiency; (9) aerosol generator response time; (10) test duct leakage test; (11) zero count rate; (12) particle counter sizing accuracy; (13) dust feeder airflow rate; (14) effectiveness of downstream mixing of aerosol; (15) neutralizer radioactivity; (16) concentration limit of particle counter; (17) pressure drop across empty test section; (18) final filter efficiency		

	ASHRAE52.2 and EN779:2002 require (1)~(13); In addition ASHRAE52.1 requires (6), (13) and (18); while ASHRAE52.2 requires(14)~(18)		
Result	Initial pressure drop, initial/ average atmospheric dust-spot efficiency, dust hold capacity	Initial pressure drop, at least 75 efficiency values, MERV under rated air flow	Initial pressure drop, initial/average efficiency, dust holding capacity, efficiency with/without electrostatic discharge
Limit	Unable to get particle size efficiency; only for dust-spot efficiency≤98%	Unable to evaluate industrial air cleaner and room air cleaners such as ozone generator and ion generator	Unable to measure particle rebound phenomena

*two particle counters can be separately installed upstream and downstream of air filters, or only one particle counter using upstream-downstream sampling sequentially.

**In order to avoid the difference in the optical and electronic system, recommend to use only one particle counter with upstream-downstream sampling sequence

2.1 Test Procedure Comparison

ASHRAE52.1 mainly uses standard artificial dust to evaluate the air filter performance under dust holding conditions. During the efficiency test, there are two ways: one is to test the efficiency for artificial dust (called ASHRAE weight arrestance), the other is used to measure the ability to reduce the staining potential of atmospheric dust (called ASHRAE dust-spot efficiency).

According to the standard, air filters with initial dust-spot efficiency less than 20% are permitted to pass arrestance test only rather than dust-spot efficiency test. Because the limit of this standard (Table 1), air filters with dust-spot efficiency higher than 98% should be tested according to other standards, e.g.IEST-RP-C001.3.

The test procedure is : firstly test the pressure drop with ambient atmospheric dust under at least 4 different air flow rate (50%, 75%, 100% and 125% of rated air flow), secondly test the opacity index of dust-spot sampler target paper upstream and downstream to determine the initial atmospheric dust-spot efficiency, thirdly ASHRAE synthetic test dust is fed to the filter gradually, and the feeding is interrupted periodically to test the dust-spot efficiency or arrestance, pressure drop and weight of dust fed, from which air filter performance change is determined and actual field performance is simulated. Test is finished when the final test condition is meet (ASHRAE 1992), and the average arrestance, average dust-spot efficiency and dust holding capacity are fixed.

Test results from ASHRAE52.1 are the average performance of air filters, while ASHRAE52.2 is used to determine the particle size efficiency and the worst case in the whole operation.

ASHRAE 52.2:1999 divides the particle size range 0.3~10μm into 12 classes with each class owning the upper and lower limit and geometric mean size, and these 12 classes are subdivided in to 3 group size range (0.3~1μm, 1~3μm and 3~10μm). According to the performance of each class of the clean filter, together with the changing performance after each of the five increment of dust loading, particle size efficiency is determined. The lowest efficiency for each class is used to determine the composite efficiency for each group, then the average of them are used to determine filters' MERV and type of filters (ASHRAE 1999).

EN 779:2002 test procedure is: firstly test pressure drop with ambient atmospheric dust under 4 different air flow rate (50%, 75%, 100% and 120% of rated air flow), secondly use the optical particle counter to sample sequentially between upstream and downstream to determine the 0.4μm particle size efficiency, thirdly liquid DEHS is fed to the filter gradually, and the feeding is interrupted periodically to test the arrestance or counting efficiency, pressure drop and weight of dust fed. Then the type of air filter is determined upon its average performance (Table 2).

EN 779:2002 especially concerns about the electrostatic effect on efficiency, which was first proposed by Technical Research Center of Finland (VVT). The performance of pretreated filters is tested, then the electrostatic discharge method is used, such as isopropanol, diesel fume, detergents or surfactants in water, after treatment test is carried out again. In 2003, Eurovent WG 4B carried out several experiments in 9 different labs about these methods from EN 779:2002. The purpose is to understand whether the results are consistent with different discharge methods and whether the performance of field actual performance is well simulated using these methods. Result shows that except for glass fibrous filter, the efficiency increases when filter is treated with surfactants in water, others are similar using remaining methods (A.Ginestet and D.Pugnet 2005). It's easy to use isopropanol to treat filter medium but may influence some filter medium. Because for the whole filter test, diesel fume is suitable and electrostatic effect can be discharged within several hours, in addition, filters exposed to diesel fume in labs can well simulate several months' actual performance, as well as it doesn't ruin filter medium and influence pressure drop, it is recommended to use diesel fume (J.Gustavsson 2003).

2.2 Type and size selection of test aerosol

ASHRAE52.1 uses atmospheric dust as test dust, however, the content and size distribution of atmospheric dust varies with different places, time, and season, even though in the same lab while in different time, the reproducibility of test results is not good. In addition, particles lager than 3μm in the atmosphere are little, while standards require to measure particles up to 10μm, and the particle irregularity will cause error (ASHRAE 1999).

ASHRAE synthetic test dust is used for dust holding capacity and arrestance in ASHRAE52.1 and EN 779:2002. During the experiment, the powder carbon in the test dust can congregate and becomes bigger than 3μm, which is different from atmospheric dust. So test results can not be used to well evaluate the dust holding capacity, lifetime and efficiency during actual operation. This defect is of concern, however, in the appendix C of EN 779:2002, it is said to continue to use ASHRAE synthetic test dust until proper and representative aerosol is developed.

Through comparing the characteristic of monodisperse PSL, polydisperse PSL and NaCl, ASHRAE52.2 decides to use polydisperse KCl solid aerosol, because this standard is concerned about the rebound effect from filters. It is easy to generate KCl, and the price is cheap, and it's not harmful for health like NaCl (ASHRAE 1999). Because the crystallization humidity of KCl is 72%, while 55% for NaCl, thus allowing a less stringent humidity requirement for the test duct (Hanley, James T et al. 2005). However, there are some problems when using KCl: (1) how to define particle size, geometric size or aerodynamic particle size? The density of KCl is about 2g/cm^3 which makes the aerodynamic particle size 1.5 times the geometric size. (2)During generation KCl becomes electrostatic which should be neutralized. (3) KCl is corrosive.

In order to solve the first problem, optical counters (OPC) with wide angle collection optics or aerodynamic particle counter (APC) can be used. When APC is used, the relationship between aerodynamic particle size and light-scattering particle size should be determined using KCl, then use PSL to calibrate APC, and use the relationship to determine the equivalent light-scattering size of KCl.

As for the particle size range, ASHRAE52.2 uses 0.30~10μm. Because particles smaller than 10μm are thought to be respirable (ASHARE 2004), and particles larger than 10μm suspending short in the air are difficult to be taken to the air filter (ASHRAE 1999), so 10μm is determined as the upper limit, and 0.3μm is determined as the lower limit upon the test range of the market particle counters. Other reasons are also listed in literature(ASHRAE 1999).

In Europe, particles larger than 3μm are not tested because these particles are rare in the atmosphere and European think they are not respirable and not harmful for health. EN 779:2002 divides the particle counter sizing range 0.2~3μm into 5 group, each boundary of which is about equidistant on a logarithmic scale.

EN 779:2002 adopts 0.4μm liquid DEHS as test aerosol, and there are several reasons:

(1) easy to generate while meeting the requirement of concentration, size range and consistency;

(2) DEHS can be used as neutral aerosol without charge, or can be through electrostatic treatment to arrive at Boltzmann charge equilibrium so as to represent the charge distribution of atmospheric aerosol.

(3) The density of DEHS is near 1g/cm^3 making the aerodynamic particle size similar with the geometric size.

(4) With OPC , liquid aerosol is more accurate than irregular solid aerosol or other nonspherical aerosols.

According to EN779:1993 and Eurovent 4/5, the average 0.4μm efficiency is similar with average dust-spot efficiency. EUROVENT carried out several experiments in 4 different labs to verify this result (J.Gustavsson 1996), so 0.4μm is selected for filter classification in EN 779:2002 to make the new standard easy to be accepted.

2.3 Filter classification

ASHRAE52.1 classifies filters upon their average arrestance and dust-spot efficiency. ASHRAE52.2 provides with a completely new method: 16 types MERV. Among them, MERV1~4 should be tested according to ASHRAE52.1. In the appendix E-1, MERV17~20 are added but without specified efficiency value. Literature [10] gives a comparison table more reasonable by recent comparison, but also need further verification (Table 2), especially with Most Penetrating Particle Size (MPPS) efficiency.

For coarse filters, efficiency decreases as dust loading increases, so the efficiency of the MERV of filters is smaller than that of new filters. For fine filters, the result is contrary to that of coarse filters.

According to EN 779:2002, filters with average 0.4μm particle less than 40% are called coarse filters (G type), others are called fine filters (F type), while F type filters in EN 779:1993 are required to have the lowest initial dust-spot efficiency 20%.

2.4 Final pressure drop

According to ASHRAE52.2, the final pressure drop is 75Pa for MERV1~4, 150Pa for MERV5~8, 250Pa for MERV9~12 and 350Pa for MERV13～16. If no final pressure drop is designated, 350Pa is preferred. According to EN 779:2002, the final pressure drop is 250Pa for G1～G4 and 450Pa for F5～F9. Different final pressure drop will influence the evaluated efficiency very much, thus the type of filters. In addition, the final pressure drop for F type filters in EN779:2002 is bigger than actual operation (typically 100~300Pa).

2.5Existing problems and suggestions

(1) Because of the test aerosols' defect, the tested efficiency, dust holding capacity and lifetime cannot reflect the actual performance. Figure 2 demonstrates the comparative diameter distribution of ISO-12103-1-A2 fine Arizona road dust, KCl aerosol and atmospheric dust. ASHRAE synthetic test aerosol is mainly composed of ISO-12103-1-A2 fine Arizona road dust. From the figure, atmospheric particles show bimodal distribution and most particles are smaller than 1μm. Although ASHRAE synthetic test aerosol is also bimodal, the particle size range is 1~10μm, so the tested results can not reflect real performance (A.Ginestet and D.Pugnet 2005; J.Gustavsson 2003). By comparison, the diameter distribution of KCl aerosol used in ASHRAE52.2 is similar with atmospheric dust. Now ASHRAE RP-1190 project group and VVT are continuing their research for new test aerosol.

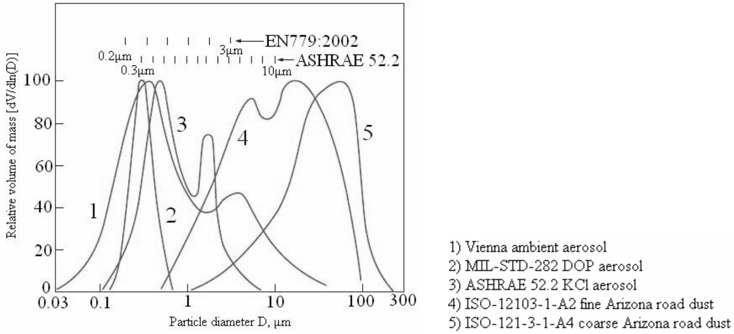

Figure 2. Size distributions for air filter test dusts and outdoor aerosol [10].

(2) As for electrostatic air filters, Swedish National Testing and Research Institute introduced minimum life efficiency (MLE) in real conditions, which is of great value for selecting air filters (J.Gustavsson 2003). Although some filters classification is not made according to the MLE after electrostatic discharge, when the MLE ratio of after treatment to before treatment is less than 10% and more, the type will be less than one class. Compared with lab experiment, the efficiency of electrostatic filters under real applications will decrease rapidly, therefore EN 779:2002 requires testing efficiency after treatment and introducing the treatment methods. ASHRAE52.2 refers the electrostatic effect but doesn't give detailed measures, and afterwards Research Triangle Park (RTI) developed new test aerosol and feeding methods for ASHRAE 52.1 and 52.2. The difference between Europe and America is that the former uses methods to discharge the electrostatic completely while the latter just discharge until the

efficiency arrive at the lowest (Hanley James T 2005).

(3) As for filter classification, the final pressure drop in EN 779:2002 is too large, and it is made based on the efficiency when untreated, so the efficiency and dust hold capacity are bigger than actual performance. It's recommended here to revise the classification upon MLE which can reflect the actual performance. Because ASHRAE52.2 doesn't measure the electrostatic effect quantitively, the efficiency of electrostatic filters is exaggerated, so when revising new classification should consider the electrostatic effect as well as test aerosol and final pressure drop.

(4) As for particle rebound, because solid KCl aerosol is used in ASHRAE52.2, this effect can be tested. But EN779:2002 is not able to test this effect, therefore it is recommended to test particle rebound phenomena quantitively when revising new standard.

(5) Because the performance between lab test and field test is different, the field test is becoming more and more concerned. At present, Europe attaches great importance to field test. For example, in 1996 Eurovent 4/10:1996 <In situ fractional efficiency determination of general ventilation filters> was published and in 2005 it was revised and became Eurovent 4/10:2005.

(6) When using outdoor air to test glass fibrous filter according to EN779:2002, because the test conditions are different, two of the test results show 0.4μm particle efficiency decreases with time, while another lab shows the different results. When using indoor air, efficiency increases with time. For electrostatic filter, the efficiency decreases as dust is loading when using outdoor air, but increases when using indoor air(J.Gustavsson 2003). This phenomenon recommends to guarantee the efficiency of inlet HEPA filters, so that whether to use indoor air or outdoor air, the results are comparative.

(7) MERV classification is accepted by ASHRAE 62.1:2004(ASHRAE 2004). In this standard the lowest efficiency filters in most buildings are larger than MERV 6. However there are also limits in ASHRAE52.2, it is recommended to adopt the valuable section in ASHRAE52.1, so that ASHRAE52.1 and its dust-spot method can be abolished.

CONCLUSIONS

From comparison of major general ventilation air filter standards between America and Europe, differences from aspects of test procedures, aerosol types and its size, air filter classification, and the final pressure drop can be found.

(1)Filter classification between them can be comparative, especially MERV17~20 in ASHRAE52.2 with EN1822:1998.

(2)The diameter distribution of KCl aerosol used in ASHRAE52.2 is similar with atmospheric dust, but test aerosols similar with atmospheric dust need further research.

(3)Concepts for electrostatic discharge between Europe and America are different from each other, and the former has been implemented in standard while the latter is still under discussion. Electrostatic effect should be especially considered when standard is revised, and classification upon MLE which can reflect the actual performance is recommended.

(4)Final pressure drop in EN 779:2002 should be lowered so as to stay close to reality. Particle rebound phenomena should be tested as ASHRAE52.2 do.

(5)Efficiency of inlet HEPA filters should be guaranteed so as to reduce the influence of test air.

(6)It is recommended that ASHRAE52.2 to adopt dust holding capacity and arrestance test in ASHRAE52.1 in order to abolish ASHRAE52.1 completely.

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Table 2. Comparison of general ventilation air filter test standards (Paolo Tronville and Richard D. Rivers 2005)

Filter performance							
ANSI/ASHRAE 52.2		ASHRAE 52.1		EN779:2002		EN1822:1998	
	Average particle size efficiency(@μm),％	Average arrestance,%	Average dust-spot	Class	Average 0.4μm	Class	MPPS efficiency,％

MERV	E_1	E_2	E_3		efficiency,%		particle size efficiency,%		
	0.3~1.0	1.0~3.0	3.0~10.0						
1	—	—	<20	＜65	＜20	G1	—	—	—
2	—	—	<20	65~70	＜20	G2	—	—	—
3	—	—	<20	70~75	＜20	G2	—	—	—
4	—	—	<20	75~80	＜20	G2	—	—	—
5	—	—	20~35	80~85	＜20	G3	—	—	—
6	—	—	35~50	85~90	＜20	G3	—	—	—
7	—	—	50~70	>90	25~30	G4	—	—	—
8	—	—	>70	>90	30~35	G4	—	—	—
9	—	<50	>85	>90	40~45	G4	—	—	—
10	—	50~65	>85	>95	50~55	F5	40~60	—	—
11	—	65~80	>85	>95	60~65	F6	60~80	—	—
12	—	>80	>90	>95	70~75	F6	60~80	—	—
13	<75	>90	>90	>98	80~90	F7	80~90	—	—
14	75~85	>90	>90	>98	90~95	F8	90~95	—	—
15	85~95	>90	>90	—	>95	F9	>95	—	—
16	>95	>95	>95	—	—	—	—	H10	85
17	—	—	—	—	—	—	—	H13	99.95
18	—	—	—	—	—	—	—	H13	99.95
19	—	—	—	—	—	—	—	H14	99.995
20	—	—	—	—	—	—	—	H14	99.995

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