DRAFT INTERNATIONAL STANDARD
ISO/DIS 16891

ISO/TC **142** Secretariat: **UNI**

Voting begins on: **2014-05-15** Voting terminates on: **2014-10-15**

Test methods for evaluating degradation of properties of cleanable filter media

Méthodes d'essai pour l'évaluation de la dégradation des propriétés des matériaux filtrants lavables

ICS: 91.140.30

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

Reference number
ISO/DIS 16891:2014(E)

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 16891 was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

Introduction

The main purpose of using cleanable filter is, of course, to separate dust particles from dirty gases. They are usually designed to be usable for as long as two to four years. However, it is very hard to design and/or select filter media properly, since their important characteristics of collection performance and residual pressure drop change with operation time. Physical and chemical properties of filter media such as degradation in tensile strength, tenacity and so on, also change with time. Those changes can damage filter media and finally can result breakage of bag filter and leakage of dust to the atmosphere. Hence the evaluation of these performances is also important for the rational design and the selection of appropriate filter media. ISO11057: 2011 “Air quality - Test method for filtration characterization of cleanable filter media”, has been published to meet the demand for the evaluation of filtration characteristics.

Changes in physical and chemical properties of filter media take place by many causes and reasons such as heat, corrosive gases, and mechanical reasons like clogging weave openings and increasing size of weave openings, the combination of those factors and so on (see Annex A). These changes are mostly adverse effects to filter media so that it can be said deterioration or degradation proceeds very slowly and thus it takes a long time before recognizable and/or measurable change appears. Furthermore the appearance of change depends on the combination of causes and fibre material. These facts are the main reason why mechanism of property changes has not been well understood despite of its practical importance [1]-[13]. Hence, the characterization or the evaluation methods for them have not been established yet [14]-[16] (see Annex B).

Nevertheless, there are demands for the establishment of a guideline for systematic characterization and evaluation of property change of filter media with respect to their relevant long-time operation not only from manufacturers of filter media, but also from producers and users of filter installations, especially the users treating combustion exhaust gases.

To evaluate degradation of filter media in laboratory, it is important that experiment can be done in a relatively short time period by using controllable single or small number of variables, i.e., causes of the change. Furthermore, the resulted effects are measureable. From this point of view, heat intensity is controllable by changing heating temperature and the intensity of corrosive gas is also controllable by changing gas concentration and thus their effects is expected to be accelerated by them. Of course the effects can be evaluated by the degradation of tensile stress.

Evaluation of property change of filter media by corrosive gases can be done by contacting filter media with those corrosive materials at any phases, i.e., gas, liquid and solid state. Test by dipping filter media into a solution of corrosive materials is easy and the resulted effects are expected to be obtained in a short period of time. Chinese Standard, GB/T 6719:2009 adopts this method [17]. Solid state test can be carried out by hard contact of filter media but it will take a long time and it is very hard to control the intensity of corrosiveness.

Test under the gaseous state takes much longer test time than liquid type test but the intensity of corrosiveness is controllable and it is much easier than the test under the solid state. Furthermore, test temperature and gas conditions except corrosive gas concentrations, are similar to the actual operation condition of filtration, which is suitable (see Annex B). Hence in this international standard, test methods for evaluating degradation characteristics of cleanable unwoven filter media with synthetic fibre by heat and corrosive gases are standardized because they are most widely used for bag filtration.

The major objective of this international standard is to specify the testing method to assess the relative change of physical performances of new and used cleanable filter media for industrial application, by exposing it in hot and/or corrosive gas conditions [18-19].

Test methods for evaluating degratadion properties of cleanable filter media

1 Scope

This International Standard specifies a standard reference test method useful to assess the relative degradation characteristics of cleanable filter media for industrial applications under standardized simulated test conditions. The main purpose of testing is to obtain the information about relative change of properties of filter media due to the exposure to the simulated gas conditions for a long time. Main target of this international standard is placed to the property change of non-woven fabric filter because they are frequently used under similar circumstances with the test gas conditions described in this international standard.
The results obtained from this test method are not intended for predicting the absolute properties of full scale filter facilities. However they will be helpful for the design of a bag filter and selection and development of appropriate cleanable filter media, and for the identification of suitable operating parameters.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4606 Textile glass – Woven fabrics - Determination of tensile breaking force and elongation at breaking by strip method

ISO 5081 Textiles – Woven fabrics – Determination of breaking strength and elongation (Strip method)

ISO 11057:2011 Air quality - Test method for filtration characterization of cleanable filter media

3 Terms and definitions

The following terms and definitions are applied in this International Standard.

3.1
aged filter sheet
filter sheet exposed under simulated high corrosive gas conditions to evaluate the change of filter properties

3. 2
air permeability
gas volume flow rate per unit filtration area at pressure drop of 124.5 Pa

3.3
average gas concentration
mean concentration of test gases during the exposure

3.4
batch type exposure chamber
chamber in which filter sheets are exposed to stationary test gas mixture

3.5
chemical degradation
degradation of chemical properties of filter media by the interaction with test gases

3.6
cleanable filter media
filter media whose aerodynamic and particle collection characteristics are re-generable or recoverable

3.7
continuous flow through method
exposing method of filter sheet, which is exposed in a continuous flow of test gas mixture
3.8
corrosive gas
chemicals which react with filter media and change its chemical and physical properties
3.9
degradation
change in physical and chemical performances of filter media by the interaction with corrosive gases
3.10
elongation
incremental length of test specimen by tensile test
3.11
elongation at maximum load
incremental length of test specimen at maximum load in tensile test
3.12
elongation ratio
ratio of elongation of test specimen to its initial length between holders or its percentage
3.13
elongation ratio at maximum load
ratio of elongation of test specimen at maximum load in tensile test to its initial length between holders
3.14
exposure chamber
chamber to expose test filter sheet to corrosive gases
3.15
filter media
material separating particulate matter from gases and characterized by its separating structure and its structural and/or textile-technological characteristics (ISO 11057)
3.16
flow-through type replacement
method to replace test gas in the batch type exposure chamber by introducing test gas continuously to the chamber
3.17
initial load
initial load applied on the test specimen at the start of tensile test
3.18
length between holders
length between holders of top and bottom holding chucks positioned at the start of the tensile test (see Figure 3)
3.19
load
tensile strength of test specimen observed in the tensile test
3.20
non-continuous flow through method
exposing method of filter sheet, which is exposed in still test gas mixture
3.21
non-woven fabric
filter media using fabric made from long fibres, bonded together with each other by chemical, mechanical, heat or solvent treatment.
3.22
number of replacement
number of test gas replacement for whole heating space volume of the test chamber
3.23
replacement of gas
exchange gas to maintain test gas concentration within certain concentration range
3.24
retention of tensile strength
ratio of tensile strength of the test specimen subjected to thermal and/or acid gas exposure to that of the test specimen without the exposure

3.25
tensile speed
speed to pull a test specimen in tensile test

3.26
strip method
method of implementing tensile test with holding whole width of the test specimen with a holding device

3.27
test gas
gas which may cause changes in physical propertied of filter media to be used for tensile test

3.28
tensile strength
value of the maximum value of load (maximum load) divided by the width of test specimen

3.29
vacuum replacement
method to replace test gas in the batch type exposure chamber by the use of vacuum

3.30
thermal exposure
expose filter media at an elevated temperature to accelerate the change of its physical properties

3.31
woven fabric
filter media using a fabric formed by weaving

4 Symbols (and abbreviated terms)

C	gas concentration	(kg. m^{-3})
$F(S)$	constant related to total surface area of filter media	(N. mm^{-1})
K	effective reaction constant	(s^{-1})
L	length between holders	(mm)
L_h	length of holder	(mm)
L_s	length of specimen	(mm)
P	load	(N)
p	pressure	(Pa)
P_{max}	maximum load	(N)
Q	flow rate of test gas	(L. min^{-1})
q	air permeability of filter	((cm^3. s^{-1}). cm^{-2})
T	temperature	(℃)
t	exposure time	(s)
V	volume of the exposure chamber	(L)
w	width of specimen	(mm)
δ	elongation	(mm)
δ_{max}	elongation at maximum load	(mm)
ε	elongation ratio	(%)
ε_{max}	maximum elongation ratio	(%)
τ	tensile strength	(N. mm^{-1})
τ_0	tensile strength of the filter media without exposure	(N. mm^{-1})
$\Delta\tau$	tensile strength difference between after and before exposure	(N. mm^{-1})

5 Principle

Physical performance of filter media mostly degrades with time because of long time exposure under severe gas conditions such as hot and/or corrosive gas condition. When filter media is exposed to hot and/or corrosive gas atmosphere such as NOx, SOx, HCl and moisture etc., those gases are considered to interact with materials in fibres and thus affect crystallinity and/or other bonding of molecules in fibre, i.e., decompose fibre in the media some extent. Hence it results irreversible damage to media and weaken its physical performances like tensile strength, elongation and so on.
Details of the above mentioned process have not been understood well yet, but tensile strength after filter media is exposed to corrosive gases and/or high temperature is expressible by the following equation by assuming that degradation reaction between corrosive gas and some reactive component in a fibre is a pseudo linear.

$$\tau(0) - \tau(t) = \Delta\tau = F(S)[1 - \exp(-Kt)] \qquad (1)$$

Here, τ: tensile strength of filter media, $F(S)$: unknown constant related to total surface area of filter media, K: effective reaction constant and is related to the degradation of media.

First derivative of Equation (1) becomes as,

$$\frac{d\Delta\tau}{dt} = -\frac{d\tau}{dt} = F(S)K\exp(-Kt) \qquad (2)$$

Equation (2) suggests that a straight line is obtained when logarithm of first derivative of tensile strength of filter media τ is plotted against exposure time t in a semi-log paper as shown in Figure 1. The slope of the line gives K (see Annex C).

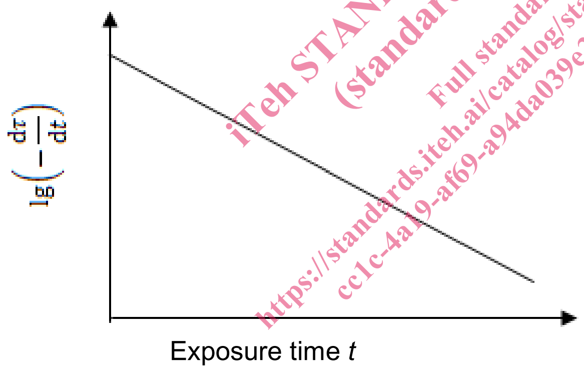

Figure 1 — Relation between gradient of tensile strength of filter media and exposure time to corrosive gas

Degradation process is usually very slow and thus measurable change of these performances usually appears after filter media has been exposed for a very long time period. Hence, it shall be accelerated by some means to evaluate the effect through experiment.
In this international standard, degradation will be accelerated by exposing filter media to a higher corrosive gas concentration and higher gas temperature.

6 Test specimen, equipment and test procedure

6.1 General

Test specimen, equipment and procedure at each step shall be chosen so as to ensure good reproducibility and repeatability of the test The equipment to prepare the samples for the measurement, generally consists of the following main components; gas supply system, exposure chamber and heating system, exhaust gas treatment unit, vacuum pump and gas analysing system. Figure 2 shows a schematic diagram of the equipment.

The test shall be carried out by the following 3 steps.

Step 1: Preparation of filter sample sheets for gas exposure
Air permeability of filter sample sheets for gas exposure shall be similar so as to obtain reliable data described in 6.2. Air permeability of filter media with size defined in 6.2.3 shall be measured and selected suitable sheets based upon the measured air permeability.

Step 2: Exposure of sheets
Sheets selected at Step 1 shall be exposed to thermal and/or corrosive gas circumstance, described in 6.3 and 6.4.

Step 3: Tensile test
Tensile strength and elongation of specimens shall be measured by the scheme described in clause 7 after tensile specimens of machine direction (MD) and transverse direction (TD) shall be cut from exposed sheets

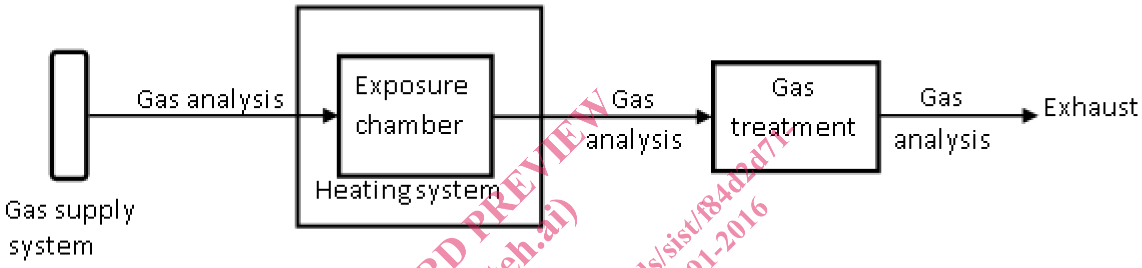

Figure 2 — Schematic diagram of equipment to prepare sample for physical performance test

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6.2 Preparation of sheets for gas exposure

6.2.1 Shape and size of tensile specimen

Rectangular shape without shoulders between holders shall be adopted in tensile test as shown in Figure 3, since filter media is soft and porous. Hence, size of the sheet of filter media to expose shall be large enough for tensile test to obtain reliable and reproducible data. According to the results shown in Annex D, measured tensile strength of nonwoven with rectangular test sheet does not depend on the width of holder w, in the range from 20 mm to 50 mm and length between holders L, from 80 mm to 120 mm (see Annex D). Hence in this international standard, rectangular shape with w=25 mm width and L=100 mm in length between holders shall be adopted and other dimensions are determined as L_h=50 mm, L_s=200 mm.

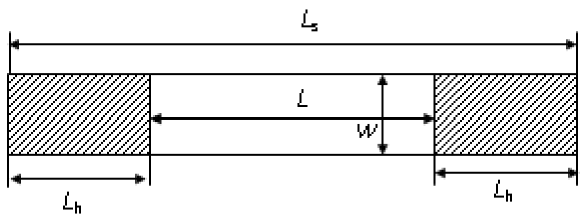

Figure 3 — Shape of tensile specimen

6.2.2 Sample sheet for exposure

To deteriorate every filter sheet equally, test gases shall contact with all fibres in the filter for whole exposure period. Therefore, continuous-flow-through type test gas flow shall be adopted in this international standard. Here in the continuous-flow-through, test gas flow through sheets during whole the exposure period as same

as actual bag filter operation. Test gases used for the exposure, are corrosive except O_2 and thus it is important to minimize gas consumption not only the cost of gas but also the safety reason. The sample sheet holder and flow rate for the exposure is specified in 6.3.
From the above consideration, size of the sheet to be exposed to test gases, shall be determined as 105 mm x 250 mm, in which test gas flows through the central part with area 65 mm x 210 mm, which shall be large enough to cut 2 tensile test specimens with 25 mm x 210 mm, as shown in Figure 4 and sample sheets shall be cut with the size of 105 mm x 210 mm in the central part of filter media roll at least 4 sheets for each direction.

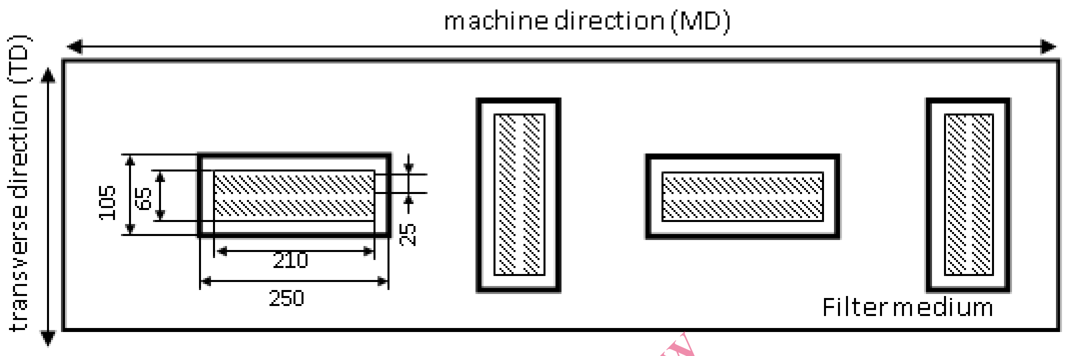

Figure 4 — Preparation of sample sheet for test gas exposure

6.2.3 Selection of sample sheet through air permeability measurement

Tensile strength of specimen strongly depends on the structure of specimen. Nonwoven filter media is composed of bonded entangling fibres. They distribute uniformly macroscopically but not microscopically because of manufacturing mechanism and it results in the unevenness of packing density or mass of fibres. Unevenness of fibre distribution in the filter, i.e., filter structure, can change physical properties such as tensile strength and/or elongation, air permeability and so on. In this sense, it is essential to eliminate the filter media with different structure from the test to avoid the fluctuation of measured data due to the unevenness of filter structure. Hence, the sample sheets with similar structure shall be selected before they are exposed to test gases structure. However, it is difficult to select from the product information about the media given by manufacturer, i.e., it is usually limited to mean value of air permeability and mass of fibres per unit area of the filter. However, air permeability of filter media is the same when filter structure is the same. This means that filter media with similar structure will show the similar air permeability so that this can be used for the selection filter media with similar structure. Hence, in this international standard, at least 4 sample sheets for gas exposure shall be selected according to the air permeability of sheet. Air permeability of each sheet shall be within ±10 % from the mean air permeability of the filter media specified by the manufacturer.

6.2.4 Filter media for exposure

In the range of this international standard, any nonwoven filter media made of synthetic fibres is used for the test, since degradation will be evaluated by the change of tensile strength and elongation of the media.

6.3 Sample preparation

6.3.1 Exposure system

In the practical bag filtration, hot and/or corrosive gases, of course, flow through filter media and thus every fibre in the filter is exposed to corrosive gas at the same concentration so that degradation takes place evenly regardless of the location in the filter, i.e., not only its surface but also its inside.
Purpose of exposing filter media to hot and/or corrosive gas circumstance is to accelerate the change of physical performances of the media by satisfying certain contact between every fibre in the filter media and corrosive gas, i.e., to prepare an aged filter sample. To meet these requirements, gas temperature and