New ISO classification systems and standards
How do they work and what do they mean?

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Outline

• ISO standardization activity and US market
• What ISO/TC142 has already done
  – HEPA and ULPA filtration
  – Gas turbine applications
• New standards being actively developed
  – PM based classification approach
  – Comparison of different synthetic dusts and test aerosols
• Conclusions
American National Standards (ANS) and ANSI

- American National Standards Institute (ANSI): administrator and coordinator of US voluntary standardization system since 1918
- ANSI facilitates the development of ANS by accrediting the procedures of standards developing organizations (SDOs)
- Accreditation by ANSI → procedures used by the standards body for developing ANS: openness, balance, consensus and due process

Examples:
- ASHRAE SPCs develop ANSI standards (committees must satisfy balance of interest, i.e. manufacturers, users, general interest)
- IEST RPs (recommended practices) are not ANSI standards
- IEST got accredited by ANSI and can also develop standards: IEST-STD-CC1246E: Product Cleanliness Levels – Applications, Requirements, and Determination

International Standards (IS) and ISO

- ANSI:
  - promotes the use of U.S. standards internationally
  - encourages the adoption of IS as national standards where they meet the needs of the user community
- ANSI is a founding member and the sole U.S. representative and dues-paying member of International Organization for Standardization (ISO)
- In many instances, U.S. standards are taken forward to ISO through ANSI, where they can be adopted in whole or in part as IS
- IS support worldwide sale of products, preventing regions from using local standards to favor local industries
- Volunteers from industry and government (not ANSI staff) carry out the work of the international technical committees
- The success of these efforts is dependent upon the willingness of US industry and government to commit the resources required to ensure strong US technical participation in the international standards process
**Relationship between ANSI and ISO standards**

- In a global market conflicting test methods and classification systems cannot "coexist" undisturbed (e.g. ANSI/ASHRAE 52.2-2012 and EN779:2012)
- Options available for the US stakeholders:
  1. To get a US standard adopted as an International Standard (IS)
      ✓ Relatively easy option when no other standard is already in place
  2. To adopt an IS as a US standard (or to make the US standard identical to the IS one, i.e. not a formal adoption but substantial)
      ✓ Obvious difficulty for acceptance (true for every other country too)
  3. To use an IS directly without making it a national one (like in the case of ISO 14644 series about cleanrooms)
      ✓ More "political" solution (in practice not so different from 2.)
- Whatever option is chosen any ISO classification system and/or standard is likely to impact to some extent the US market too
- Worthwhile to work together with ISO TCs to make them as good as possible

**ISO Standards: when**

ISO standards provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.

ISO Standards:

1. Respond to a need in the market (ISO reacts to a request)
   **Request** from industry or other stakeholders such as consumer groups.

2. Are based on global expert opinion
   Developed by groups of experts from **all over the world**. The experts negotiate all aspects of a standard, including scope, key definitions, content.

3. Are developed through a multi-stakeholder process
   Technical committees made up of experts from the relevant industry, but also from consumer associations, academia, NGOs and government.

4. Are based on consensus
   Developing ISO standards is a consensus-based approach and comments from stakeholders are taken into account.
ISO/TC142 scope and structure

Title: Cleaning equipment for air and other gases

Scope: Standardization in the fields of terminology, classification, characteristics, and test and performance methods for air and gas cleaning and disinfecting equipment for general ventilation and industrial applications.

Excluded:
- exhaust gas cleaners for gas turbines and IC engines in mobile equipment, this being within the scope of other ISO technical committees;
- filters for personal protection equipment which are the field of work of technical committee ISO/TC 94;
- cabin filters in mobile equipment covered by ISO/TC 22, 23 and 127.

- 11 working groups (Convenors: 4 Americans, 1 Canadian, 4 Europeans, 1 Japanese, 1 vacant position)
- About 200 experts from 19 countries

ISO/TC142 current participation

19 P-members (participating countries), see table below
18 O-members (observing countries)

<table>
<thead>
<tr>
<th>Austria (ASI)</th>
<th>Korea, Republic of (KATS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium (NBN)</td>
<td>Netherlands (NEN)</td>
</tr>
<tr>
<td>Brazil (ABNT)</td>
<td>Pakistan (PSQCA)</td>
</tr>
<tr>
<td>Canada (SCC)</td>
<td>Russian Federation (GOST R)</td>
</tr>
<tr>
<td>China (SAC)</td>
<td>Spain (AENOR)</td>
</tr>
<tr>
<td>Finland (SFS)</td>
<td>Sweden (SIS)</td>
</tr>
<tr>
<td>France (AFNOR)</td>
<td>Switzerland (SNV)</td>
</tr>
<tr>
<td>Germany (DIN)</td>
<td>United Kingdom (BSI)</td>
</tr>
<tr>
<td>Italy (UNI)</td>
<td>USA (ANSI)</td>
</tr>
<tr>
<td>Japan (JISC)</td>
<td></td>
</tr>
</tbody>
</table>
ISO/TC142 Working Groups

WG1 "Terminology" (P. Dyment, UK)
WG2 "UV-C technology" (vacant, ...)
WG3 "General ventilation filters" (D. Thornburg, USA)
WG4 "HEPA and ULPA filters" (R. Vijayakumar, USA)
WG5 "Dust collectors, droplet separators and purifiers" (A. Sorensen, USA)
WG6 "Flat sheet media testing" (N. Nance, USA)
WG7 "Durability of cleanable filter media used in dust removal applications" (C. Kanaoka, Japan)
WG8 "Gas-phase air cleaning devices" (M. Forslund, Sweden)
WG9 "Particulate air filter intake systems for rotary machinery and stationary internal combustion engines" (U. Johansson, Sweden)
WG10 "Aerosol filters for nuclear applications" (P. Cortes, France)
WG11 "Portable room air cleaners for comfort applications" (Z. Sultan, Canada)

ISO/TC142 published standards (1 of 2)

• ISO 6584:1981 "Cleaning equipment for air and other gases - Classification of dust separators"
• ISO/TS 21220:2009 "Particulate air filters for general ventilation - Determination of filtration performance" (no classification included)
• ISO 29464:2011 "Cleaning equipment for air and other gases – Terminology" (will replace EN 14799)
• ISO 29463-1 to -5:2011 "High-efficiency filters and filter media for removing particles in air" (will replace EN 1822)
  – Part 1: Classification, performance testing and marking
  – Part 2: Aerosol production, measuring equipment and particle-counting statistics
  – Part 3: Testing flat sheet filter media
  – Part 4: Test method for determining leakage of filter elements - Scan method
  – Part 5: Test method for filter elements
ISO/TC142 published standards (2 of 2)

- ISO 29462:2013 "Field testing of general ventilation filtration devices and systems for in situ removal efficiency by particle size and resistance to airflow" (published also as EN ISO 29462)
  - Very similar to ASHRAE Guideline 26-2012
- ISO 10121-2:2013 "Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 2: Gas-phase air cleaning devices (GPACD)" (published also as EN ISO 10121-2)
  - Slightly different from ASHRAE 145.2-2011
- ISO 29461-1:2013 "Air intake filter systems for rotary machinery - Test methods - Part 1: Static filter elements" (published also as EN ISO 29461-1)
  - No ANSI or other US document on this subject

HEPA and ULPA filters testing and classification

- ISO 29463-x "High-efficiency filters and filter media for removing particles from air - ..." in five parts (published in October 2011)
- First ever ISO test method for HEPA and ULPA filters
- Approach and structure similar to EN 1822 (efficiency at MPPS as reference)
- Inclusion of photometer scan test (local efficiency)
- Mentioning other approaches (e.g. sodium flame)
- Part 1: Classification, performance testing and marking
- Part 2: Aerosol production, measuring equipment, particle-counting statistics
- Part 3: Test method for flat sheet filter media
- Part 4: Test method for determining the leakage of filter elements (scan method)
- Part 5: Test method for determining the efficiency of filter elements
- Includes filter media discharging procedure in Annex C of Part 5 (IPA liquid) referring to ISO/TS 21220:2009
### ISO 29463 classification system

<table>
<thead>
<tr>
<th>Filter class (number)</th>
<th>Limit for overall value</th>
<th>Limit for local value</th>
<th>Test procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 15 E</td>
<td>0.5</td>
<td>5</td>
<td>Overall efficiency test</td>
</tr>
<tr>
<td>ISO 20 E</td>
<td>0.5</td>
<td>5</td>
<td>Local efficiency test (test2)</td>
</tr>
<tr>
<td>ISO 25 E</td>
<td>0.5</td>
<td>5</td>
<td>Filters of group E cannot and shall not be leak tested for classification purposes</td>
</tr>
<tr>
<td>ISO 30 E</td>
<td>0.5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>ISO 35 H</td>
<td>0.025</td>
<td>0.025</td>
<td>X</td>
</tr>
<tr>
<td>ISO 40 H</td>
<td>0.025</td>
<td>0.025</td>
<td>X</td>
</tr>
<tr>
<td>ISO 50 U</td>
<td>0.005</td>
<td>0.005</td>
<td>X</td>
</tr>
</tbody>
</table>

* See also Table 1.
* Local penetration values lower than those given in Table 1 may be agreed upon between the supplier and customer.
* Efficiency test method may be applied as given in ISO 29463-4:2011, 4.2.
* Efficiency test of each individual filter applies as per ISO 29463-5:2011, Clause 4.
* Comment shall be made in test protocol and classification that filter is tested in accordance with ISO 29463-4:2011, Annex B.

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### Filter class and group

<table>
<thead>
<tr>
<th>Overall value</th>
<th>Local values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency %</td>
<td>Penetration %</td>
</tr>
<tr>
<td>ISO 15 E</td>
<td>0.5</td>
</tr>
<tr>
<td>ISO 20 E</td>
<td>0.5</td>
</tr>
<tr>
<td>ISO 25 E</td>
<td>0.5</td>
</tr>
<tr>
<td>ISO 30 E</td>
<td>0.5</td>
</tr>
<tr>
<td>ISO 35 H</td>
<td>0.025</td>
</tr>
<tr>
<td>ISO 40 H</td>
<td>0.025</td>
</tr>
<tr>
<td>ISO 50 U</td>
<td>0.005</td>
</tr>
<tr>
<td>ISO 55 U</td>
<td>0.005</td>
</tr>
<tr>
<td>ISO 60 U</td>
<td>0.005</td>
</tr>
<tr>
<td>ISO 65 U</td>
<td>0.005</td>
</tr>
<tr>
<td>ISO 70 U</td>
<td>0.005</td>
</tr>
</tbody>
</table>

* See 7.5.2 and ISO 29463-4.
* Local penetration values lower than those given in this table may be agreed upon between the supplier and customer.
* Filters of group E cannot and shall not be leak tested for classification purposes.
* For group H filters, local penetration is given for reference MPSS particle scanning method. Alternate limits may be specified when photometer or oil thread leak testing is used.
ISO 29463 series adoption process

Slow process of acceptance and implementation (as expected)
The Netherlands adopted ISO 29463:2011 as a Dutch standard while keeping EN1822:2009

CEN/TC195 RESOLUTION N. 12/2011
Replacement of EN 1822:2009 series by the adoption of ISO 29463:2011 series
CEN/TC 195 "Air filters for general air cleaning" notes the publication of ISO 29463:2011 and decides to wait for the systematic review in 2013 of EN 1822:2009 to collect the information necessary to harmonise the two standards.

CEN/TC195/WG2 convened by Mr. Klamp (Germany) will meet in June 2013
Revision of EN1822 with the intention of replacing the current European standard with ISO 29463 newer version (when available)

ISO 29461-1:2013

- First ever test method for gas turbine air intake application
- No classification system, as requested from the USA during public enquiry
- First standard to adopt the new approach with IPA vapor to discharge the flat sheet of filter medium
- Dr. Toshiaki Hayashi (Functional Materials Research Center; Toyobo Co., Ltd.) “I proposed IPA-vapor discharging method as a substitute method of IPA immersion method.”
New approach in discharging media samples

  - Some media (membrane) suffer from efficiency reduction not related to the inhibition of the electrostatic charges
  - Not easy to obtain a media sample belonging to the roll used to manufacture the air filter
  - Full scale filters treatment not practical (IPA released in the environment)
- IPA vapor approach developed in ISO/TC142/WG9 (gas turbines)
- Proposal from Japan circulated in June 2010
- Filter media exposed to saturated isopropanol (IPA) vapor

Round robin test
Flat sheet of media treated with IPA vapor

Work coordinated by Ulf Johansson (graph taken from his report)
8 laboratories participating from China, Europe and USA
- Material A; Pleatable glass
- Material B; Pleatable synthetic
- Material C; Bagfilter synthetic
- Material D; Bagfilter glass
- Material E; Cellulosic material

Results obtained between October and December 2010
Discharging vessel used at Politecnico di Torino

IPA vapor exposure duration

Steady state at 24 hours

Efficiency vs Time
Laboratory 1

[Graph showing efficiency vs time for different samples labeled A, B, C, D, E with vapour exposure duration indicated]

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New stuff from ISO/TC142

- ISO 16890 "Air filters for general ventilation" series: new approach
- ISO/CD 16890-1 "Part 1: Technical specifications, requirements and efficiency classification system based upon Particulate Matter (PM)"
  - PL: T. Caesar (Germany); DIS due September 21st 2013
- ISO/AWI 16890-2 "Part 2: Measurement of fractional efficiency and air flow resistance"
  - PL: D. Thornburg (USA); CD due July 17th 2013
- ISO/AWI 16890-3 "Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured"
  - PL: W. Fekkes (The Netherlands); CD January 11th 2014
- ISO/AWI 16890-4 "Part 4: Conditioning method to determine the minimum fractional test efficiency"
  - PL: M. Britt (USA) & M. Sauer-Kunze (Germany); CD due July 17th 2013

Classification systems for comfort applications filters

ANSI/ASHRAE 52.2-2012
- Particle size range 0.3-10 µm; KCl aerosol (solid) neutralized
- Classification system based on MERV 1 to 16
- Average minimum efficiencies in 3 size groups: 0.3–1; 1–3; and 3–10 µm
- Only MERV levels 13 and above make use of all three particle size ranges

EN 779:2012
- Particle size range 0.2-3 µm; DEHS aerosol (liquid); no need to neutralize
- Classification system based on the averaged fractional efficiency obtained through the whole artificial clogging process (ASHRAE dust) in laboratory
- Filters placed in categories determined by their averaged arrestance (G filters) and by the averaged efficiency on 0.4 µm particles (M and F filters)
- Further constraint for F filters: a minimum efficiency value must be satisfied by the filter and its media (including the discharged state)
- In practice most of the times the efficiency of the discharged media determines the filter class (F7, F8 and F9)
**EN 779:2012 classification table**

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>Final test pressure drop (Pa)</th>
<th>Average arrestance ($f_m$) of synthetic dust (%)</th>
<th>Average efficiency ($f_{eff}$) of 0.4 μm particles (%)</th>
<th>Minimum Efficiency * of 0.4 μm particles (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>G1</td>
<td>250</td>
<td>50 ≤ $f_m$ &lt; 65</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>250</td>
<td>65 ≤ $f_m$ &lt; 80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td>250</td>
<td>80 ≤ $f_m$ &lt; 90</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G4</td>
<td>250</td>
<td>90 ≤ $f_m$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Medium</td>
<td>M5</td>
<td>450</td>
<td>-</td>
<td>40 ≤ $f_{eff}$ &lt; 60</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>M6</td>
<td>450</td>
<td>-</td>
<td>60 ≤ $f_{eff}$ &lt; 80</td>
<td>-</td>
</tr>
<tr>
<td>Fine</td>
<td>F7</td>
<td>450</td>
<td>-</td>
<td>80 ≤ $f_{eff}$ &lt; 90</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>F8</td>
<td>450</td>
<td>-</td>
<td>90 ≤ $f_{eff}$ &lt; 95</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>F9</td>
<td>450</td>
<td>-</td>
<td>95 ≤ $f_{eff}$</td>
<td>70</td>
</tr>
</tbody>
</table>

*Minimum efficiency is the lowest efficiency among the initial efficiency, discharged efficiency and the lowest efficiency throughout the loading procedure of the test.

Laboratory test data (Politecnico di Torino) measured on the same filter monitored on the left.

Data on grey background obtained during Eurovent 2004 Round Robin Test.
Critical points in classification systems

- **Averaged efficiency** much higher than “in-service” efficiency
- Obtained choking air filter with synthetic dust (surface filtration) till 450 Pa
- Energy efficiency considerations would rule out 450 Pa in any case
- EN779:2012 classification adds **minimum efficiency** values for F7-F9 classes; averaged values still there (end users believe them)
- F5 and F6 classes simply renamed M5 and M6: no minimum efficiency required (same for G filters)
- To take into account **as much as possible** the actual behavior of air filters:
  - No artificial increase of the efficiency values;
  - Availability of data about the minimum efficiency for any filter class.
- ASHRAE S2.2-2012 approach much more realistic, however:
  - MERV classes are conventional (not immediate to make calculations)
  - Particle size range not appropriate for some applications (e.g. behavior of MERV 8 filters in urban environments)

PM based approach for classification system

- Limits to particulate pollution set by cognizant authorities by means of PM values (mass concentration)
- Idea: to obtain the mass concentration downstream of the filter by using its fractional efficiency data
- Upstream aerosol size distribution determined by the aerosol physics
- Particle size distribution about the same in every city of the world: normalization
- What changes is the concentration (much higher in highly polluted areas)
What’s new with ISO 16890 series

• Classification of air filters based solely on their initial removal efficiency to PM10, PM2.5 and PM1 atmospheric aerosol fractions

• Minimum particle collection efficiency of the filter element (including also the discharged condition) or filter media in the size range 0.3-10 μm

• New method with IPA vapor could be used to discharge the whole filter

• If new method proves not to be feasible on the whole filter (due to safety and repeatability), flat sheet or media pack sample from an identical filter shall be discharged with IPA vapor to provide the fractional efficiency in clean and discharged conditions

• Fractional efficiency curve (average of clean and discharged conditions) then used to calculate the efficiency for PM10, PM2.5 and PM1

• Standardized particle size distribution of the related atmospheric aerosol fraction to be defined
Normalized particle size distribution

**Normalized particle size distribution**

![Normalized particle size distribution graph](image)

Aerodynamic Diameter [μm]

Particle Volume [%]

0,01 0,10 1,00 10,00 100,00

Aerodynamic Diameter [μm]

Rural

Urban

Courtesy of Dr. R. Romanò

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Particle size distribution and filter efficiency

**Particle size distribution and filter efficiency**

![Particle size distribution and filter efficiency graph](image)

Aerodynamic Diameter [μm]

Efficiency

0,01 0,10 1,00 10,00 100,00

Aerodynamic Diameter [μm]

Rural

Urban

Efficiency

Courtesy of Dr. R. Romanò

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ASHRAE 52.2 vs. ISO/CD 16890-1 rating

EN 779 vs. ISO/CD 16890-1 rating

ISO-TC142-WG3_N0098_Filter_data_overview_public_V2 (no free circulation)


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ISO/DIS 15957:2013

- ISO/DIS 15957 “Challenge contaminants for testing air cleaning equipment”; PL: Y. Oogaki (Japan)
- Currently under public review (ends September 4th 2013)
- The purpose is to gather in a single international standard the information about the dusts used for laboratory air filter ageing
- JIS 11 is finer than the other synthetic dusts (see graph)
Interlaboratory ISO/TC142/WG3 test

Objectives
• To compare Dust Holding Capacities (DHC) of JIS11 and ASHRAE test dust
• To confirm the reproducibility and consistency of the DHC test results with JIS and ASHRAE test dust for different filters
• To measure the initial efficiencies of untreated filters with DEHS and KCl test aerosol and to obtain additional information on the compatibility of efficiency results with DEHS, KCl and JIS11 dust generated with a fluidized bed generator

Tested filters
• 2"-pleat filter, approximately G4 (EN779:2012)
• Typical glass fibre bag filter, approx. 450 mm deep, F7 (EN779:2012)
• Typical 4V glass paper media minipleat filter, F9 (EN779:2012)

Test Dusts
• NEW class 11 JIS Test Dust (as per JIS Std. Z8901), The NEW class 11 JIS test dust is produced by a jet milling process while traditional class 11 JIS test dust is produced by a ball milling process. The material composition of new dust is not changed but the particle size distribution is shifted to slightly smaller sizes than the traditional ball milled JIS test dust.
• ASHRAE Test Dust as per ASHRAE Std. 52.2-2007
• Test results taken from presentation prepared by Mr. Y. Ogaki
Initial $\Delta P$

G4

F7

F9

Efficiency 0.4 $\mu$m

G4

F7

F9

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ΔP vs. Dust Fed on G4 filter

Scatter of JIS dust data wider at final pressure drop compared to ASHRAE dust

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ΔP vs. Dust Fed on F7 filter

JIS Data within the scatter of ASHRAE data

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Lessons learned

- The DHC values differ very much whatever synthetic dust is used
- What is the maximum variation that is acceptable?
- Does it make any sense to make such measurement if do not manage to reduce the variability?

- KCI and DEHS fractional efficiency data can differ above 1 µm
- DEHS provides more consistent data below 1 µm (no neutralization needed)
- KCI more realistic above 1 µm because it mimics the bouncing effect
- KCI aerosol and JIS dust allow achieving 10 µm but JIS dust tends to clog the filter during measurement
Sustainability work items

- ISO 12249 series is about sustainability: “Particulate air filters for general ventilation - ...”
  - Part 1: Method of calculation for the life cycle cost for air cleaning devices”; PL: P. Dyment (UK) - DIS in preparation
  - Part 2: Method of calculation for the energy performance of air cleaning devices and for the classification of the energy performance”; (Project leader to be elected)
  - Part 3: Application of the life cycle assessment to air cleaning devices”; PL: M. Tryjefaczka (France)

WG6 "Flat sheet media testing"

- ISO/NP 14086-1 "Flat sheet filter media - Part 1: Fractional efficiency test for general ventilation applications"

- ISO/NP 14086-2 "Flat sheet filter media - Part 2: Fractional efficiency test for high final pressure drop applications"
Changes related to ISO standards

• If ISO HEPA/ULPA standards accepted → update of production line test equipment and personnel
• Methods would be uniform throughout different subsidiaries
• Test methods devoted to specific applications
• Example: several test methods for filters at gas turbine air intake, easier to interact with customers, less importance of proprietary test methods
  – 29461-1 "Static filter elements"
  – 29461-2 "Cleanable filter systems"
  – 29461-3 "Mechanical integrity of filter elements"
  – 29461-4 "In-situ testing of filter systems"
  – 29461-5 "Static filter systems in marine and offshore environments"
  – 29461-6 "Cleanable filter elements"
• Easier to compare and buy filter media tested according to the same procedure

Thank you for your attention!

Questions?

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