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|  | <b>Product Specification<br/>RQ 200 for Lamp and<br/>General Application</b> | SPEC_Z_LW_04<br>page 1 of 9             |
| Authors: 12.06.2008<br>Ludwig Stier<br>Dr. Sigrun Rakus                           | Approved: 12.06.2008<br>Frithjof Raesch                                      | Released: 12.06.2008<br>Frithjof Raesch |

### Introduction:

This kind of quartz is made from 99.8% of pure quartz (SiO<sub>2</sub>). **RQ 200** is a high temperature and high viscosity melting quartz glass, which is especially designed for high quality light source applications.

**RQ 200** is produced as tubes and is in general used as burner- and exhaust tubes for the production of (e.g.):

- high-pressure discharge street lamps,
- cosmetically lamps, purification lamps,
- halogen lamps or projector lamps.

### Physical Properties:

|  |                    |                                     |             |
|--|--------------------|-------------------------------------|-------------|
| Linear thermal expansion coefficient       | (20 - 320) °C      | [10 <sup>-6</sup> K <sup>-1</sup> ] | 0.54        |
| Modulus of elasticity                      |                    | [GPa]                               | 66          |
| Poisson-Number                             |                    | [1]                                 | 0.17        |
| Density                                    |                    | [gcm <sup>-3</sup> ]                | 2.2         |
| Transformation temperature                 |                    | [°C]                                | ca. 1200    |
| Viscosity                                  | [dPas]             |                                     | [°C]        |
|  | 10 <sup>14.7</sup> | Strain point                        | 1167        |
|  | 10 <sup>13.2</sup> | Annealing point                     | 1255        |
|  | 10 <sup>7.6</sup>  | Softening temperature               | 1760        |
|  | 10 <sup>4</sup>    | Working temperature                 | 1990        |
| Devitrification range                      |                    | [°C]                                | 1000 - 1700 |
| Max. working temperature                   |                    |                                     | [°C]        |
| Permanent with cooling to room temperature |                    |                                     | 1000        |
| Permanent with cooling to 300 °C           |                    |                                     | 1200        |
| Short time                                 |                    |                                     | 1300        |
| Electrical resistance                      |                    | [Ωcm]                               | [°C]        |
|  |                    | 10 <sup>4</sup>                     | 1660        |
|  |                    | 10 <sup>6</sup>                     | 1000        |
|  |                    | 10 <sup>8</sup>                     | 510         |
| Dielectric constant                        | at 20 °C, 1 MHz    | [1]                                 | 3.7         |
| Dielectric loss factor                     | at 20 °C, 1MHz     | [10 <sup>-4</sup> ]                 | < 1         |
| Refractive index                           | at λ = 587.6 nm    | [1]                                 | 1.459       |
| Thermal conductivity                       | at 20 °C           | [Wm <sup>-1</sup> K <sup>-1</sup> ] | 1.4         |

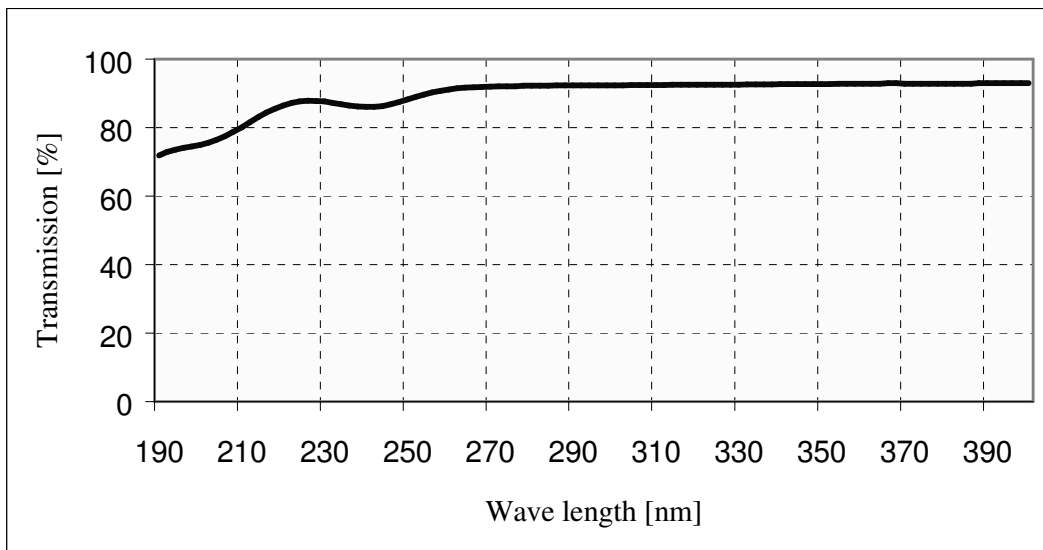
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**Transmission Properties:**

Limits for transmission values of 1 [mm] wall thickness:

|                            |      |      |      |      |
|----------------------------|------|------|------|------|
| wave length $\lambda$ [nm] | 200  | 250  | 360  | 400  |
| transmission T [%]         | > 65 | > 85 | > 90 | > 91 |

**Transmission curve RQ 200**



**Chemical Composition:**

SiO<sub>2</sub> [%]                    99.9

**RQ 200** contains the following typical impurities in ppm:

| Elements | Typical | Elements | Typical |
|----------|---------|----------|---------|
| Al       | 15      | Li       | 0.7     |
| Ca       | <1      | Mg       | 0.1     |
| Fe       | < 0.3   | Na       | 0.7     |
| K        | < 1     | Ti       | 1       |

For the OH<sup>-</sup> content of **RQ 200** the following description and values need to apply:

|                   |              |              |
|-------------------|--------------|--------------|
| <b>RQ 200</b>     | unbaked      | appr.120 ppm |
| <b>RQ 200 V4</b>  | vakuum baked | < 5 ppm      |
| <b>RQ 200 V40</b> | vakuum baked | < 1 ppm      |

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### Visual Characteristics:

#### Standard Inspection Lighting:

The term “visible” is used for flaws (typically > 0.25 mm) that can be seen under general overhead inspection illumination. The light source is typically 0.75 – 1.25 m above the piece, with the tubing viewed at a distance of 0.3 – 0.6 m from the inspector, with a white/black background.

#### **Airlines**

##### A: Airline (enclosed):

##### Definition:

A void, wholly within the tube wall including those bumping up the surface.

##### Limits:

| Size                     | Total Cumulative Length of Airlines per Piece | Maximum Airline Width |
|--------------------------|---|-----------------------|
| Up to 15.0 mm OD         | 12 %  | 0.15 mm               |
| 15.1 mm OD to 25.0 mm OD | 12 %  | 0.25 mm               |
| 25.1 mm OD to 30.0 mm OD | 12 %  | 0.30 mm               |
| 30.1 mm OD to 40.0 mm OD | 12 %  | 0.40 mm               |
| 40.1 mm OD to 50.0 mm OD | 12 %  | 0.70 mm               |
| 50.1 mm OD to 60.0 mm OD | 12 %  | 1.00 mm               |

Customer specified tubes may have requirements for less than 12 % total airlines and smaller airline width. We offer 2 additional air line classes: class 10 and class 6 with 10 % respective 6 % total cumulative length of airlines per piece.

##### B: Open ID or OD Airline:

##### Definition:

A void, open to the ID or OD surface, which has sharp, knifelike edges.

##### Limits:

None permitted (above visual detection of 0.1 mm width).

##### C: “Bumpy” ID or OD Airline:

##### Definition:

A raised area in the wall of the tubing, directly over an enclosed void near the surface, on the ID or OD.

##### Limits:

10 % maximum total cumulative length of airlines per piece, except none so thin as to open with the pressure of a gloved fingernail.

None permitted in tubing < 6 mm OD at the OD surface (above visual detection of 0.1 mm width).

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## Dirty

### Definition:

Removable foreign material adhering to the tube surfaces.

### Limits:

- None permitted on the ID. Exceptions: A light, uniform degree of cutting quartz dust is permitted at the tube ends. Material designated fc (furnace cut) is permitted a moderate degree of cutting dust on the ID.
- No obvious fingerprints.
- No spot larger than 2.0 mm in diameter or smaller spots adding to 2.0 mm diameter within any 300 mm of length.
- Readily apparent, non-uniform cutting dust on the OD is not permitted. Material designated fc (furnace cut) is permitted a moderate degree of cutting dust on the OD.
- No clearly visible water spot larger than 2.0 mm diameter, or several adding up to more than 2.0 mm equivalent diameter area (3.14 mm<sup>2</sup>) within 300 length of tubing.
- Readily apparent, non-uniform graphite on the OD is not permitted.

## Checks, Cracks and Tears

### Definition:

Crack: A thin break line in the wall that extends through part or all of the wall. The line may also be circular as from impact damage. Cracks are readily visible.

Check: Small fracture perpendicular to the circumferential surface, "V" or chevron shaped extending inward.

Tears: Small fractures on the outside surface of the quartz with minor ">" (chevron) shapes or diamond "<>" shapes running along the surface. Fine tears are similar to scratches. Rejectable tears are readily visible and can be felt with a short fingernail.

### Limits:

No readily visible Cracks, Checks or Tears under Standard Inspection Lighting.

## Scratch

### Definition:

A narrow line abrasion of the surface (over 0.3 mm wide).

### Limits:

- No scratches adding up to half the tube length in the longitudinal direction.
- No single scratch exceeding 150 mm.
- No scratches on the inside surface.
- No scratches around the tube adding to twice the tube circumference.

## Scuffs

### Definition:

Relatively broad lines, bands and/or areas of surface abrasion.

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Limits:

- Long length (> 300 mm): Readily visible areas adding up to 12.5 mm of length and complete circumference for 300 mm in average.
- Short length ( $\leq$  300 mm): Readily visible areas adding up to 1/20 of the tube length.

**Vapour**

Definition:

A haze of silica deposited on the tube surface seen when viewed with the unaided eye.

Limits:

- Reject any degree having a colour other than white.
- Reject if more than 10 % of either the ID or OD surface contains the haze.

**Discoloration**

Definition:

General bulk colour other than “water white” in the body of a quartz tube.

Limits:

Degree of any type is limited by chemical purity limit as specified in “chemical composition”.  
Note: V 40 bake – slight darkening may occur.

**Striations**

Definition:

Circumferential surface variations resulting in optical distortions, over the full length of the tube.

A: Standard Striation:

Limits:

- Accept light striations uniformly distributed around either a portion or the full circumference of the tube.
- Alternatively other striation levels can be agreed and documented by means of a customer limit sample.


B: High Quality Striation:

Definition:

High Quality Striation is clear quartz tubing with minimal optical distortions. Originally defined for optical applications. High Quality Striation requires no striations on the ID or OD surfaces that would cause unacceptable shadows in a light beam projecting from the tube ID. High Quality Striation evaluations require a high degree of visual discrimination and are presently made as “best judgement call”.

Limits:

- OD or ID bumpy striations are not acceptable.
- Reject striation levels that exceed any customer agreed upon limit samples.

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Visual Striation Rating Table Summary (OD grater than 13 mm)

| Grade | Quality Level | Uniformly Distributed (ID or OD)                               | Individual / Discrete Lines (ID or OD)  |
|-------|---------------|--|---|
| 1     | High          | Only faint striations visible.<br><br>Can't be felt.           | One or two individual striations or flow lines that appear to be heavier than the faint uniform striations.<br><br>Can't be felt.         |
| 2     | Standard 1    | Readily visible striations.<br><br>Still can't be felt.        | One or more individual striations or flow lines that appear to be heavier than the faint uniform striations.<br><br>Still can't be felt.  |
| 3     | Standard 2    | Readily visible striations.<br><br>Can just barely feel.       | One or more individual striations or flow lines that appear to be heavier than the faint uniform striations.<br><br>Can just barely feel. |
| 5     | Reject        | Many very readily visible striations.<br><br>Can readily feel. | Several individual striations or flow lines that appear to be heavier than the faint uniform striations.<br><br>Can readily feel.         |

Note: Above criteria is based on unaided visual inspection.

## Inclusions

### A: Enclosed Inclusions:

#### Definition:

Foreign matter wholly enclosed within the tube wall (over 0.3 mm).

#### Limits:

- Long length (> 300 mm): Coloured or black line – Max length of 25 mm.
- Short length: (≤ 300 mm): Coloured or black line – Max length of 1.0 mm.
- Individual inclusion (spot): Max 0.5 mm diameter.
- Cluster (3 or more individual inclusions where each inclusion passes individually):
  - Long length (> 300 mm): Max of 2 clusters in any 300 mm of tubing length.
  - Short length: (≤ 300 mm): Max of 1 cluster per tube.

### B: ID Exposed Inclusions:

#### Definition:

Foreign matter apparently exposed to the bore surface (over 0.3 mm).

#### Limits:

None permitted.

### C: OD Exposed Inclusions:

#### Definition:

Foreign matter exposed to the outside surface (over 0.3 mm).

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Limits:

- Individual inclusion (spot): Max 0.5 mm diameter.
- No more than 1 inclusion cluster in any 300 mm of tubing length.

Note on inclusion clusters (enclosed or OD):

Consider a cluster to be 3 or more individual inclusions with each inclusion within a millimetre of the next inclusion, with each inclusion visible to an unaided eye (> 0.3 mm), and with each individual inclusion passing the max size specification for an individual inclusion.

**Dimensional Characteristics:**

**Standard Tubing – Tolerance guidelines**

| OD            | Size<br>Wall<br>(as a % of nominal OD) | OD<br>Tolerances<br>(as a % of nominal OD) | Wall<br>Tolerances<br>(as a % of nominal Wall) | Siding<br>Max<br>(as a % of nominal Wall) | Ovality<br>Max<br>(as a % of nominal OD) | Bow<br>Max<br>(prorate to actual tube's length) |
|---------------|--|--|--|---|--|---|
| under 5 mm    | ≥ 18 %<br>(thick wall)                 | ± 2.5 %                                    | ± 10 %   | 10 %                                      | 2.0 %                                    | 2 / 1000 mm                                     |
| 5 to 6 mm     | ≥ 18 %<br>(thick wall)                 | ± 2.0 %                                    | ± 10 %   | 10 %                                      | 2.0 %                                    | 1.5 / 1000 mm                                   |
| > 6 to 20 mm  | ≥ 18 %<br>(thick wall)                 | ± 1.5 %                                    | ± 10 %   | 10 %                                      | 2.0 %                                    | 1.5 / 1000 mm                                   |
| under 6 mm    | < 18 %                                 | ± 2.0 %                                    | ± 10 %   | 10 %                                      | 2.0 %                                    | 2 / 1000 mm                                     |
| > 6 to 20 mm  | < 18 %                                 | ± 1.25 %                                   | ± 8 %  | 8 %                                       | 2.0 %                                    | 1.5 / 1000 mm                                   |
| > 20 to 40 mm | All                                    | ± 1.125 %                                  | ± 8 %  | 8 %                                       | 2.0 %                                    | 1.5 / 1000 mm                                   |
| > 40 to 60 mm | All                                    | ± 1.125 %                                  | ± 10%  | 10 %                                      | 2.0 %                                    | 1.5 / 1000 mm                                   |

| Length Range<br>Finished Cut | 30 mm OD and under<br>Length Tolerances | Over 30 mm OD<br>Length Tolerances |
|------------------------------|---|------------------------------------|
| Under 150 mm                 | ± 0.5 mm                                | ± 1.0 mm                           |
| 150 up to 300 mm             | ± 0.75 mm                               | ± 1.0 mm                           |
| 300 up to 1000 mm            | ± 1.5 mm                                | ± 1.5 mm                           |
| 1000 up to 2000 mm           | ± 3 mm                                  | ± 3 mm                             |
| 2000 and above               | ± 6 mm                                  | ± 6 mm                             |

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### Outside Diameter (OD)

Definition:

All diameters in all cross-sectional planes along length (“all points in”).

### Inside Diameter (ID)

Definition:

Minor axis diameter at the tube ends (as measured by plug gages).  
ID is not a criteria unless specifically given in print, order or standard.

### Wall Thickness (WT)

Definition:

All wall thicknesses on the circumference of both ends.

### Ovality

Definition:

Out of Round Diameter (circular run-out tolerance).  
Expressed as a percent =  $(\text{Max OD} - \text{Min OD}) / \text{Specified Nominal OD} \times 100 \%$   
Expressed as an amount = Max OD - Min OD

### Siding (Eccentric wall)

Definition:

Difference between greatest and least wall thickness, at either tube end.  
Expressed as a percent =  $(\text{Max Wall} - \text{Min Wall}) / \text{Specified Nominal Wall} \times 100 \%$   
Expressed as an amount = Max Wall - Min Wall

### Bow

Definition:

Amount of deviation to a straight edge, usually a curve.  
Measurement =  $\text{Max Gap to a Straight Surface} / \text{Length of Tube}$

Note: Bow is often specified as a maximum amount over a given length (such as per 1000 mm). The maximum deviation per tube is prorated for the actual length of the tube.

### Cut Length

Definition:

All lengths, parallel to the centreline or any physical part of the tube.

Limits:

fc (Furnace Cut) standard spec: specified length +/- 10 mm.

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### **Cutting Irregularities**

#### Definition:

Deviation from a smooth, perpendicular end cut.

-Step cut: Junction of two intersecting cutting planes.

-Slant cut: Not perpendicular.

-End Protrusion: Point on end.

-Chip: Piece of material missing from the OD/ID surface at the tube end.

#### Limits:

Refer to Raesch Specification "General Criteria for Cutting of Quartz Glass Tubes".

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### **Effective Documents:**

Sortierkriterien RQ 200 for Lamp and General Application (RK\_Z\_LW\_13)  
Raesch Specification "General Criteria for Cutting of Quartz Glass Tubes"