MEASURING THE SPECULAR REFLECTION ON SURFACES
(GLOSS MEASUREMENT)

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1  FUNDAMENTALS ON MEASURING THE SPECULAR REFLECTION ON SURFACES

1.1  Introduction

For the manufacturing and processing industries of products like varnish, plastics, leather or metals with treated surfaces, a constant surface quality is of vital importance. In almost all sectors of industry it is necessary to provide a clearly defined and good surface quality.

Material, shape and gloss of the surfaces are usually determined by many different factors, like the wishes of the clients, fashion and, of course, often technical reasons.

Modifications in the production, new suppliers, material fluctuations and many other circumstances can cause differences in the gloss of the products which often lead to complaints or even rejections after quality checks in the finishing industry. That is why a perfect and objective means to judge the gloss has recently been gaining special importance, as clients become more exacting.

An objective assessment of the gloss of smooth surfaces can be obtained with the reflectometers described in many national and international standards such as e.g. ISO 2813. Most of them are employed for quality assurance and surface quality optimization in the paints and plastics industries as well as for paper and print media or anodic oxidation coatings of aluminium.

ISO 2813:2014 - Paints and varnishes — Determination of gloss value at 20 degrees, 60 degrees and 85 degrees specifies a method for determining the gloss of coatings using the three geometries of 20°, 60° and/or 85° of measurement angle. The method is suitable for the gloss measurement of non-textured coatings on plane, opaque substrates but can also be used for other solid surfaces but shall generally not be applied for luminescent coatings. Gloss measurements on curved or uneven surfaces in accordance with this ISO are possible only comparatively for identical coating materials and application parameters.

ISO 7668:2010 - Anodizing of aluminium and its alloys — Measurement of specular reflectance and specular gloss of anodic oxidation coatings at angles of 20 degrees, 45 degrees, 60 degrees or 85 degrees. The ISO notes that the specular reflectance characteristics of anodized aluminium do not always behave in the normal manner because of its property of double reflection. The reason for that is that the reflected light comes partly from the film surface and partly from the underlying metal. The ISO notes further that measurements of these properties are not independent of the apparatus being used.

The TAPPI T 480 standard as well as the newer ISO 8254:2009 part 1 and 2 deals with the assessment of the “gloss” of a paper or board surface at 75° viewing angle. ISO 8254:2009 part 3 specifies a method for measuring the specular gloss of paper and board at an angle of 20° to the normal to the paper surface. It is applicable chiefly to highly glossy surfaces, such as cast-coated, lacquered, highly varnished or waxed papers and high-gloss ink films.
1.2 Gloss measurement and interpretation of results

What is gloss?

“Gloss is defined as an optical property of a surface, characterized by its ability to reflect light specularly”. Terms and definitions about “gloss” are given in ISO 4618:2014.

As such subjective gloss perception by a human eye is not a physical characteristic, it is impossible to measure directly. Apart from the objective measured value of reflection, the individual impression of the observing person plays an important part in surface assessment. Language, however, cannot classify gloss sufficiently by terms like e.g. high gloss, glossy, silky matt or matt.

The International Committee of Illumination (CIE) defines gloss as a phenomenon where bright reflex lights or images of bright objects are seen on a surface, created by the surface’s directional reflectivity.

Figure 1 shows the reflection distribution (indicatrix) for three different kinds of surface. The first case (1) is a high gloss surface reflecting the incident light beam almost completely at the complementary angle. The diffuse share is very small.

The second case of reflection (2) is a normal gloss surface reflecting the light in a smaller directed share and a diffuse one.

The third case (3) is an ideally matt surface reflecting the incident light beam equally diffuse to all directions.

A glossmeter measures only the gloss degree of the light share reflected from the surface in complementary direction to the incident angle. While colorimetry considers only the diffuse share of the entire surface reflection, gloss measurement concentrates on the directed share in the complementary angle. But as gloss is measured in the visible range of wavelengths, the sample colour influences the measured gloss value to a certain extent. Therefore you should try to compare samples showing no appreciable difference in hue and lightness.
In order to judge the gloss impression of a surface, the observer will examine shape and lightness of the reflected image. As paint films are not optically smooth, irregularities of the surface structure may influence these two factors of gloss impression. Typical changes in the profile shape of a paint film are shown in the following figure.

![Diagram showing changes in profile of a three-angle beam falling on different varnished surfaces.](image)

Fig. 2: Changes in profile of a three-angle beam falling on different varnished surfaces

In the left figure (1) the varnish film is very smooth and almost the total share of incident light is reflected directly. The profile of the reflected light is similar to that of the incident beam, but less intense.

If the surface is a relatively smooth one, but with some volume reflection (i.e. small surface irregularities of less than 1 micrometer in diameter) both components - reflected gloss and backscattered light (center figure (2) in fig. 4) - are clearly discernible. This means the reflected image is slightly distorted, owing to the diffraction by the volume reflection, and overlaid by the diffuse share. Moreover, the image is less intense.

When light falls on a slightly textured paint film (right picture (3)), the share reflected at the complementary angle decreases considerably while diffuse reflection increases, leading to a substantial reduction of intensity and a widening of the three-angle profile.

1.3 What is the measure of gloss?
A frequently asked question: “Is the reflectometer value given in terms of percentages?” The answer is “NO!” A reflectometer value is a dimensionless quantity without units but some newer standards call them gloss units (GU). The job protocol or test record must indicate the incident angle employed for every measuring value.

1.4 Measuring principle
In practice, the viewing geometries described in ISO 2813 are used world-wide. They have proved suitable for measuring all existing types of gloss like painted, plastic, metallic and paper surfaces within the scope of these standards.

ISO 2813 defines three measuring angles for gloss measurement by these criteria:

- 20° measuring angle for high-gloss samples
- 60° measuring angle for medium-gloss samples
- 85° measuring angle for near matt samples
As this verbal classification lacks precision, the correct measuring angle is determined by measuring the sample at 60°. For 60°-glossmeter values over 70 GU, viewing geometry 20° is suitable, and for 60°-glossmeter values below 30 GU, viewing geometry 85° is best.

Therefore the following definition holds true for the selection of the correct angle:

- 60° measuring angle for 60°-glossmeter values between 30 GU and 70 GU
- 20° measuring angle for 60°-glossmeter values over 70 GU
- 85° measuring angle for 60°-glossmeter values below 30 GU

Nevertheless, the viewing geometry must not be changed during the measurement. Comparative measurements must be made at the same angle, because different geometries reveal different aspects of gloss.

The recommended glossmeter value of the 60°-angle may, of course, be passed if some samples in a series reach or exceed the limits. For instance if a series of samples is measured with 60° angle and some of them have higher gloss values of 75 GU or 80 GU it is not necessary nor mandatory to measure this samples with 20° angle.

![Optical set-up principle of a three-angle glossmeter](image)

For inter-instrument agreement within reasonable tolerances, ISO 2813 fixes the maximum deviation of apertures (diaphragm apertures). As long as these tolerances are met, glossmeter values show errors of less than one gloss unit over the whole measuring range.
**Measurement standards (certified reference material)**

All these international standards and definitions ensure that gloss readings show an excellent comparability and reproducibility which is extremely important for production sites.

The Hach® (former company Hach Lange or Dr. Lange) glossmeters REFO 3 and REFO 60 are in compliance with the requirements of the old DIN 67530 as well as of the new ISO 2813:2014 and others.

For the surveillance of inspection, measuring and test equipment Hach provides certified calibration standards for normal gloss as well as for high gloss measurement. The standards are traceable to national and international standards as required for ISO 2813 or ISO 9002ff,

**Medium-gloss standard B**

For internal and external quality audits and certifications by ISO 9002ff, Hach® offers sets of certified test tiles for REFO 3/3D (LZM160) and REFO 60/60D (LZM161), consisting of four black glass standards with different gloss degrees, supplied with a certificate of nominal values and valid date for self-checks and an optional service schedule. These so-called Medium-gloss standard B can be used for testing linearity of the gloss meters.

**1.5 Take measure correctly – with RST-technology**

The quality of the results is a decisive criterion in innovative quality control systems. To maintain the excellent quality level of the measuring results, Dr. Lange developed the reference beam technology RST.

For every measurement two light beams (measuring and reference beam) are registered in parallel. The reference beam serves as a current reference standard. Disturbances during the measurement like e.g. ageing effects of lamp, filters or fluctuations in the energy supply are detected immediately and compensated by the RST-technology.

As one of the leading glossmeter producers, Hach have had his REFO-systems tested at the Federal Institute of Materials Research and Testing (BAM) in Berlin in compliance with the specifications of DIN 67530. Having passed the test, all glossmeters were granted the test mark.
All glossmeters accomplish the requirements of the old DIN 67530. On the basis of the test record ref. 5.4-5444 dated July 2nd, 1993, issued by the Federal Institute of Materials Research and Testing (BAM) in Berlin, the German trademark committee "Deutsche Gesellschaft für Warenkennzeichnung GmbH" granted permission for Hach/Lange glossmeters to be labelled "DIN-tested", register no. 2F010 at that time. This is the only means for the user to compare his measuring results world-wide.

1.6 Influence of surface colour to the gloss measurement
The observer sometimes wonders how colour influences gloss. To a certain extent, colour appearance and lightness of the sample affect the glossmeter value. This influence, however, is negligible and therefore not taken into account. Nevertheless you should bear in mind that when comparing the reflectance values of different samples, they should be equal or similar in colour appearance and lightness, too.

1.7 Repeatability and Reproducibility limits of gloss measurements
Within the dispose of ISO 2813 the repeatability limit r is the value below which the absolute difference between the mean values of two separate sets of three measurement values, obtained on the same product, can be expected to lie under repeatability conditions. In this case, the results are obtained on identical material by one operator in one laboratory within a short interval of time using the same equipment and following the ISO 2813 test method. The reproducibility limit R is the value obtained on identical material but by operators in different laboratories. r and R limits are given in the table below with a 95% probability:

<table>
<thead>
<tr>
<th>Geometry</th>
<th>Repeatability limit r</th>
<th>Reproducibility limit R</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°</td>
<td>3 GU</td>
<td>4 GU</td>
</tr>
<tr>
<td>60°</td>
<td>2 GU</td>
<td>3 GU</td>
</tr>
<tr>
<td>85°</td>
<td>1 GU</td>
<td>2 GU</td>
</tr>
</tbody>
</table>
2 THE MEASURING INSTRUMENTS

2.1 The universal glossmeters REFO 3 and REFO 3D

The glossmeters REFO 3 and REFO 3D are portable three-angle glossmeters designed for safe and easy application everywhere in production and in the lab. The instrument body is a sturdy casting fit for daily practice.

REFO 3 and REFO 3D operate battery-powered in portable mode or if desired also mains-operated in laboratory / production environment where an electrical socket is available.

REFO 3D includes a data memory for up to 450 measurements. Moreover, REFO 3D measures not only ordinary gloss but also metal gloss. In this case, a special metal standard LZM155 is required for calibration of the metal gloss measuring range.

REFO 3 and REFO 3D offer the following measuring programs:

- One-angle measurements at 20°, 60° or 85° as single or multi-measurements including the determination of mean value, standard deviation and coefficient of variability.

- Three-angle measurements as single or multi-measurements including the determination of mean value, standard deviation and coefficient of variability.

- Gloss difference measurements against a gloss reference standard.

Glossmeter REFO 3D includes an extra program for continuous measurement of the gloss value. Moving the instrument over a large surface (e.g. the hood of a car, paper sheets) controls the uniformity of the surface.
### 2.2 The handy glossmeters REFO 60 and REFO 60D

The glossmeters REFO 60 and REFO 60D are designed for high-quality one-angle gloss measurement during production, i.e. measuring, deciding and correcting while production is in full swing. The reading is displayed at once at the touch of a button.

With the universal viewing geometry of 60°, REFO 60 and REFO 60D measure the entire production program.

REFO 60D includes a data memory for up to 300 measurements which can be transmitted to the PC.

Moreover, REFO 60D measures not only ordinary gloss but also metal gloss at 60°. In this case, a separate metal standard LZM154 is required.

### 2.3 Reference Standards

For calibration, working standard A is employed in compliance with old DIN 67530 and ISO 2813. It is a polished high-gloss black glass tile with a refractive index of $n = 1.567$.

The standards are calibrated against a quartz wedge pursuant to DIN 67530 and ISO 2813 at BAM (Federal Institute of Materials Research and Testing), Berlin. Gloss values of the standards usually in the range of 20° approx. 92, 60° approx. 94 and 85° approx. 99.

Till this moment, REFO 3D and REFO 60D are the only glossmeters measuring not only ordinary gloss but also metal gloss. To measure high-gloss metal surfaces with REFO 3D or REFO 60D, metal standard described in ISO 7668 must be used for calibration.

This standard has a polished aluminium surface with a transparent quartz coat as protection against corrosion. Metal standards are also calibrated against a quartz wedge as specified in ISO 7668 at BAM (Federal Institute of Materials Research and Testing), Berlin. It is important to know that the calibration values of the metal standard cannot be compared with those of standard A!

The calibration values of each viewing geometry are indicated on the standards and stated in the quality certificate (acc. to DIN/ISO 9000ff) to assure the traceability of these calibration data (important for quality audits).

The glossmeter value of a calibration standard becomes void as soon as its surface is damaged. The glossmeter standards should be exchanged every two years at least and also if they are dirty or degrade.
2.4 Calibration
In glossmeters REFO 3/3D and REFO 60/60D employs automatic calibration.
That means the glossmeter recognizes when it is fitted to the standard and a measurement is performed. The meter calibrates automatically. No further settings are required. When the calibration standard is exchanged (normally after two years of usage), the new calibration values has to be entered and stored in the instrument.

2.5 Statistics
Glossmeters REFO 3 and 3D permit statistical calculations by merely touching a button. You can make a reliable assessment of the surface’s quality. The unequivocal readings are documented as print-out, indicating mean value, standard deviation, and coefficient of variability.

3 Applications of Hach´s glossmeters
There is practically no limit to the industrial application of glossmeters. The following examples give just a general survey on the major fields of application.

Painted surfaces
Almost all paints and varnished surfaces e.g. in the automobile industry are measured to check and document gloss. The gloss degree determines whether the surface is matt, silky matt or glossy, and whether it has pigment occlusions.

Plastics
Plastics tend to suffer surface modifications during production and finishing which can be detected by gloss measurement. Examples of application are plastic housings, automobile trims etc.

Reflectors
The reflectance of e.g. high-gloss aluminium reflectors for headlamps and lamps are checked with glossmeters to guarantee constant and optimum reflection values.

Furniture
Furniture, especially office furniture, is checked to assess the gloss of the coating or varnish. The gloss of office furniture must not exceed a certain degree to avoid light reflexes keeping disturbing and tiring the eye.

Printed surfaces
Printed surfaces like e.g. cardboards, folding boxes or packings of cosmetics are checked for constant gloss degrees, because their visual appearance is an important quality feature.
Glass panes

Glass panes and other glass objects are measured directly to check their quality. In this case, the effect of manifold outside influences like cleaning agents, caustic acids and the like is evidenced.

Foils

For a reproducible gloss measurement of foils, it is necessary to use a suction plate which takes in the foils by creating a vacuum.

Polished surfaces

Polished surfaces are checked with glossmeters to control the quality of the surface treatment. Modifications of the surface can be caused by higher roll pressure force, lower pass speed or burnishing compounds of different granulation.

Paper and paperboard

Gloss measurement helps to assign papers and cardboards to different categories, e.g. matt coated or glossy types.

Fogging test, according to DIN 75201

Fogging means the condensation of volatile components of the car trims on the windows, especially on the windscreen. Fogging on the windscreen can deteriorate the driver’s sight.

You can use the glossmeters to determine the fogging value with a viewing geometry as specified in DIN 67530 / ISO 2813. The fogging value is the relation between the glossmeters value of the glass pane with the fogging precipitation and that of the same glass pane without fogging precipitation in terms of percentages.

After setting the calibrated instrument REFO 3D or REFO 60D on the clean glass pane you can read off the measuring value Ro. For this procedure, the glass pane lies on a mask over a matt black basis. The mask ensures that the instrument is 0.1mm above the glass pane to avoid pollution of the glass pane or blurring the precipitation during the measurement.

Before measuring the precipitation with REFO you have to check the glass pane for discernible drops or transparent films over the entire surface which might misrepresent the measuring results. A sample is considered worse when it shows considerably more substance on the test pane in comparison with another sample (with identical glossmeter value). You should try to avoid the use of formulation components leading to the formation of crystals on the test pane. Put the glass pane into the mask. Then put the instrument on the glass pane and read off the glossmeters value. Measure every glass pane four times. Take the mean of these four measurements.
### 3.1 Technical Information*

**International Rules and Standards:**
- ISO 2813, ASTM D 523
- ISO 8254, TAPPI T 480
- ISO 7668, DIN 67530

**Operation:**
- REFO 3/3D: mains / batteries
- REFO 60/60D: battery

**Viewing Geometries:**
- REFO 3/3D: 20°, 60°, 85°
- REFO 60/60D: 60°

**Dimensions:**
- REFO 3/3D: 200x56x80mm l/w/h
- REFO 60/60D: 140x40x80mm l/w/h

**Measuring Surface:**
- 20°: approx. 9 x 9mm
- 60°: approx. 17 x 9mm
- 85°: approx. 100 x 10mm

**Weight:**
- REFO 3/3D: 750g
- REFO 60/60D: 430g

**International Calibration Standard A:**
- REFO 3/3D: LZM151
- REFO 60/60D: LZM150

**Warranty:**
- REFO 3/3D: 3 years (EU only)
- REFO 60/60D: 3 years (EU only)

**High gloss Standard Metal:**
- REFO 3D: LZM155
- REFO 60D: LZM154

**Test tile set:**
- REFO 3/3D: LZM160
- REFO 60/60D: LZM161

(* All data subject to technical modification)