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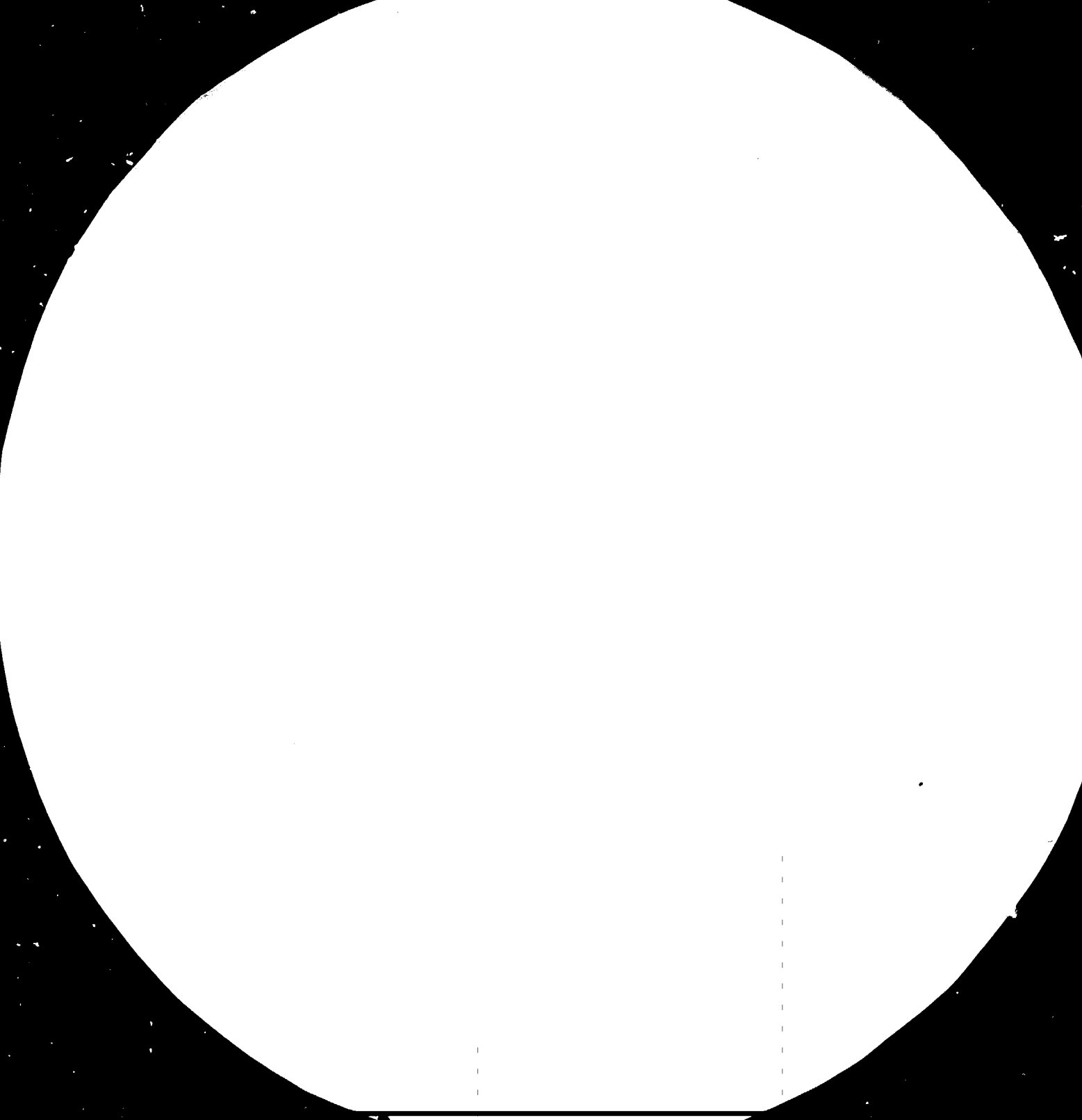
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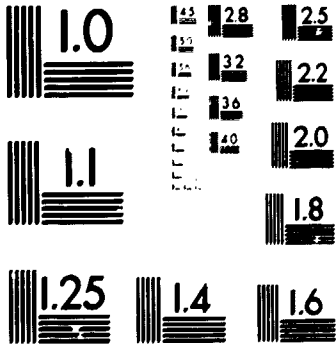
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**MICROCOPY RESOLUTION TEST CHART**  
**NATIONAL BUREAU OF STANDARDS**  
**STANDARD REFERENCE MATERIAL 1010a**  
**(ANSI and ISO TEST CHART No. 2)**

# 13089

UNITED NATIONS  
INDUSTRIAL DEVELOPMENT ORGANIZATION

Distr.  
LIMITED  
UNIDO/IO.564  
23 November 1983  
ENGLISH

( CERAMIC  
MAIN QUALITY FACTORS OF TABLEWARE )

Basic Information\*

Prepared by C. Čermák, Z.A. Engelthaler, and Mr. Nový  
for UNIDO-Czechoslovakia Joint Programme for International  
Co-operation in the Field of Ceramics, Building Materials  
and Non-metallic Minerals Based Industries,  
Pilsen, Czechoslovakia

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V.83-64242

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**ABSTRACT**

The presented paper deals with tableware classification and quality control tests. It presents the most important types of ceramic tableware, their characteristics and examples of body composition bringing lowered firing temperatures.

The main quality control tests are mentioned and methods of testing are briefly described. Review of recommended limiting values of test results enables the comparison of practical data obtained.

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## INTRODUCTION

The UNIDO-Czechoslovakia Joint Programme for International Co-operation in the Field of Ceramics, Building Materials and Non-metallic Minerals Based Industries in Pilsen was requested by UNIDO Vienna to provide Messrs. TIRDO, Tanzania with an information on quality testing of tableware.

This paper was elaborated on the basis of this request presenting the classification of tableware and its characteristic properties as well as survey of qualities to be tested.

The paper can assist producers in the developing and least developed countries in the matter of tableware testing focussed on quality control.

## I. CLASSIFICATION OF TABLEWARE

Ceramic tableware can be produced in a large technological variety from which the most important types are as follows:

### 1. Stoneware Tableware

is produced with a vitreous but opaque type of the body. The blend contains naturally vitrified clays, such as stoneware clays or suitable ball clay. Non-plastic constituents to control the shrinkage and to regulate the coefficient of thermal expansion of the green body and flux to lower the firing temperature and to save energy during firing can be added.

Stoneware tableware can be produced in the single-firing or double-firing technology. The bisque firing temperature fluctuates between 800 - 1000°C while the glost firing temperature reaches usually 1250°C. By applying fluxes, the glost firing temperature can be lowered down to 1180 - 1200°C.

At present, stoneware is produced on the commercial scale chiefly as cooking ware and some tableware with low lead, glossy or matt glazes which are mostly opaque coloured or rarely translucent. Tableware, produced from stoneware, shows high mechanical properties, low porosity and excellent resistance against cracking.

Table 1 shows two types of the stoneware tableware possible body composition with corresponding firing temperatures.



Table 1 Stoneware Tableware Body Compositions  
with Corresponding Firing Temperatures

Type	Content %				Firing temperature °C
	Stone-ware Clays	Silica	Feldspar	Fluxes as Feldspar, Talcum and Dolomite	
Body I	40-50	45	5-15	-	1250-1280
Body II	60	15	-	25	1200

The increased content of well vitrifying stoneware clays, lower content of silica and higher content of fluxes, in which aside feldspar other fluxing materials are presented, decrease the firing temperature from 1250 - 1280°C down to 1200°C.

## 2. Earthenware Tableware

is produced with the non-vitreous, opaque, off-white or coloured bodies. Different types of the body composition can be applied in which aside the China clay, ball clay, silica also potassium or sodium feldspars are the prevailing fluxes or lime siliceous body composition can be developed. Non-traditional fluxes, such as phonolites can be added to lower the firing temperature.

Earthenware tableware is always produced in the double firing technology. If decoration is applied, three or more firings are necessary to obtain the final product. The bisque firing temperature can fluctuate in a wide interval between 980 to 1280°C. The glaze firing temperature reaches 900 to 1120°C.

At present, earthenware tableware is produced in different developing countries which introduce usually the dinnerware manufacture by the earthenware composition. Leadless or leadlow glazes are applied usually as glossy opaque glazes to cover the colour of the body. Tableware, produced from earthenware, must be carefully balanced to avoid cracking or peeling of glazes due to a porous body. Earthenware dinnerware always shows high average weight of one piece, being usually above 400 g.

Table 2 shows the earthenware tableware body compositions with corresponding firing temperatures. The earthenware tableware of type I represents so called hard type as showing lower porosity but its firing temperatures are the highest. The lime-siliceous body composition in type II results in higher porosity. The type III is a

compromise applicable in all cases where good plastic clays and kaolins are available in such qualities that they show white or light colour after firing.

Table 2 Earthenware Tableware Body Compositions with Corresponding Firing Temperatures

Type	Content %				Bisque Firing Temper. °C	Glost Firing Temper. °C
	Kaolins and clays	Silica	Feldspar	Lime-stone		
I	50-55	35-45	6-12	-	1280	1120
II	50-55	35-45	-	5-10	1080	980-1020
III	75-85	15-20	0-5	-	1160	960-1020

### 3. Vitreous China Tableware

is produced with high grade, fully vitrified body. The blend is composed of a mixture of washed kaolins, light - the best white - burning clays and finely ground silica and fluxes.

Vitreous China tableware is produced mostly in the single-firing technology but the double-firing is also applied. If bisque is produced, it is fired at the temperature 1180 - 1250<sup>o</sup>C, while glost firing is realized at 1180 - 1280<sup>o</sup>C. The single firing manufacture is more rational, however, it is more sensitive to keep high quality products.

At present, the vitreous China tableware is produced on the mass scale specially on the American Continent where it represents a common type of lower priced table-ware and the hotel tableware as showing thicker body and being less fragile than the porcelain and, therefore, being more resistant against breakage. Semi-opaque, opaque or transparent glazes are applied with under-glaze or on-glaze decorations and/or with different coloured glazes. The vitreous China tableware shows high mechanical properties, fully vitrified but opaque body and good resistance against cracking of the glaze.

Table 3 brings the vitreous China tableware body compositions with corresponding firing temperatures.

Body types I and II are composed of natural clays and kaolins which contain silica. The difference in the firing temperature depends on the type and amount of flux applied. Type III is composed of pure components

and, therefore, silica is added in the form of siliceous sand.

Table 3 Vitreous China Tableware Body Compositions  
with Corresponding Firing Temperatures

Type	Content %			Firing Temperature °C
	Kaolins and Clays	Silica	Feldspar and Pegmatite	
I	50	-	50	1250
II	55	-	45	1300
III	52	35	13	1250

#### 4. Porcelain Tableware

represents the high quality ware of purest whiteness and considerable transparency. The body is composed of high grade in average washed kaolins, off-white burning clays, silica and feldspar.

Porcelain tableware is traditionally produced in the double firing process. The bisque firing of porcelain differs from that of earthenware as follows: the first firing is at a low temperature 800 - 1000°C, the body and the non-fritted glaze being subsequently matured together in the second firing at about 1320 - 1450°C, depending on the type of porcelain. The new technologies try to develop the single firing process when high plastic clays and kaolins can provide mechanical properties of the green body high enough for glazing and for manipulation.

The porcelain tableware is produced mostly in the European countries. It is provided by the glossy transparent or rarely by semi-opaque glaze, being decorated with all possible decorating techniques. Tableware produced from porcelain shows low average weight of one piece, being usually below 200g, good mechanical strength of the body, hard scratch resisting glaze, thermal shock resistance and resistance against the crazing of the glaze. It represents the most luxury type of tableware.

Table 4 shows the porcelain tableware body compositions with corresponding firing temperatures.

Table 4 Porcelain Tableware Body Compositions  
with Corresponding Firing Temperatures

Type	Content %			Glost Firing Temperature °C
	Washed Kaolins and Clays	Silica	Feldspar	
I	35-60	20-40	15-25	1350 - 1450
II	43-66	12-30	18-33	1350 - 1450
III	40-60	20-40	20-30	1300 - 1400
IV	25-35	20-45	30-40	1250 - 1350
V	25-34	11-45	30-55	
VI	2- 5	15-25	75-81	1100 - 1200

Types I and II represent the hard porcelain products with the highest firing temperature. The hotel porcelain, type III, is the transitting type between the hard and soft porcelain products. As an example, the composition of the dental porcelain is given. All the compositions clearly show that the higher is the content of feldspar in the porcelain body, the lower is the glost firing temperature.

## II. QUALITIES TO BE TESTED - METHOD OF TESTING

### Absorptivity

#### Method of testing:

Dried and weighted testing samples of a product are saturated with water and weighted again. The absorptivity is calculated according to the following formula:

$$A = \frac{m_s - m_d}{m_d} \cdot 100 \quad \%/$$

where            A    ..... absorptivity  
                   $m_s$  ..... mass of saturated sample  
                   $m_d$  ..... mass of dried sample

### Thermal shock resistance

Thermal shock resistance is determined by the temperature difference of heated and cooled specimens by which their bending strength is lowered to 2/3 of the bending strength of samples which did not undergo the temperature change.

#### Method of testing:

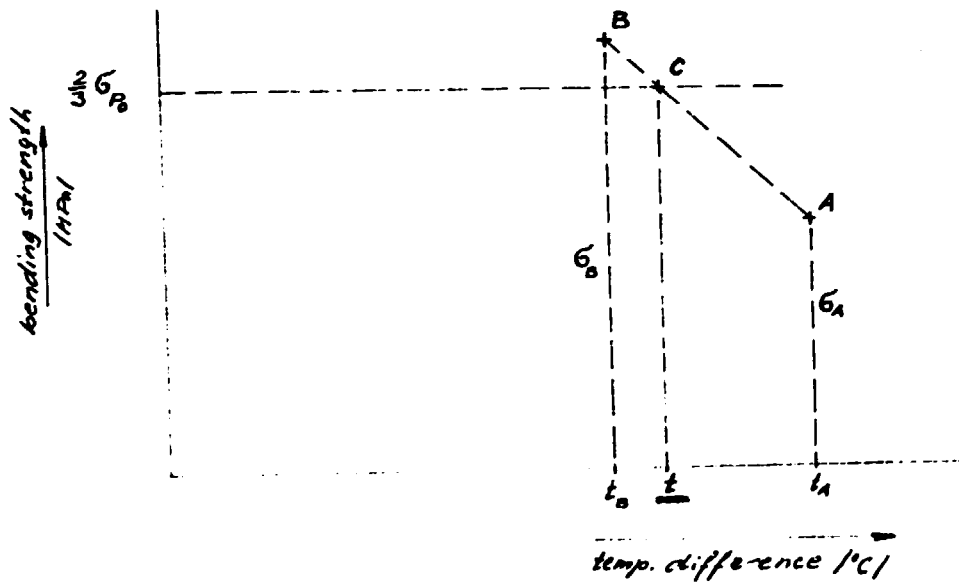
First of all the bending strength of samples is determined. Then the samples are heated to the temperature 100°C higher than the temperature of cooling water (20 ± 10°C) and cooled quickly by submerging for 5-minute period into this water. The samples are dried after removing in the temperature 120°C for 2 hours and after cooling down to the ambient temperature, the bending strength is determined.



The next collection of samples (minimally 5) is heated up to the temperature 50°C higher and all the cycle is repeated. The test ends after the bending strength is lowered under 2/3 of original value.

The result is determined from the last two values of temperature difference (the last above 2/3 of original bending strength and the first under this value).

A/ Graphically:



B/ According to the formula:

$$t = \frac{t_B \left( \frac{2}{3} \sigma_{P0} - \sigma_A \right) - t_A \left( \frac{2}{3} \sigma_{P0} - \sigma_B \right)}{\sigma_B - \sigma_A}$$

The temperature difference  $t$  determines the thermal shock resistance of the tested sample.

### Bending strength

Bending strength is the bending stress by which the testing sample is broken.

#### Method of testing:

The sample supported by two edges is loaded by continuously increasing load until it is broken. The leading edge is placed in the middle between two supporting edges. The breaking load is recorded and the bending strength is calculated according to the following formula:

$$P_o = \frac{M_b}{W_o}$$

where  $M_b$  ..... is the bending moment induced by the breaking load  
 $W_o$  ..... is section modulus of tested sample

### Acid and lye resistance

Acid resistance is the ability of products to resist the effect of sulphuric acid or hydrochloric acid. It is expressed by the percentage of the sample's mass after acid effect related to the mass of original sample.

Lye resistance is the ability of products to resist the effect of sodium hydroxide solution. It is expressed by the percentage of the sample's mass after lye effect related to the mass of original sample.

Toxic element release

Method of testing:

The acetic acid 4% v/v is used as reagent. The surface of the tableware to be tested shall be clean and free from grease or other material liable to interfere with the performance of the test. The tableware tested shall be placed on a flat horizontal surface in a room at the temperature 19 to 21°C and filled to the extreme edge of the rim with acetic acid (4% V/V).

The tableware shall be covered to minimize contamination and evaporation. After 24 hours, the cover shall be removed, the acid stirred thoroughly to ensure homogeneity of the solution and an appropriate portion of the solution removed for analysis. The amount of lead and cadmium extracted shall be determined by atomic absorption spectrophotometry. The results are expressed in mg/dm<sup>2</sup> of tableware in contact with acetic acid (4% V/V).

Colour - whiteness

The whiteness of tested material is determined by the comparison of the sample with operating standard of whiteness in testing device. The whiteness of tested material is expressed in percentage of absolute whiteness.

The review of qualities of selected tableware types is presented in the following table:

Table 5 Review of Qualities of Selected Tableware Types

Quality	Product			
	stoneware tableware	earthenware tableware	vitreous china	porcelain tableware
Absorptivity	up to 2%	up to 5%	up to 2%	0%
Thermal shock resistance	150 °C	150°C	200°C	230°C
Bending strength	35 MPa	30 MPa	35 MPa	40 MPa
Acid and lye resistance	96 %	96 %	98 %	100 %
Toxic elements release	1.0 mg Pb/dm <sup>2</sup> 0.1 mg Cd/dm <sup>2</sup>	1.0 mg Pb 0.1 mg Cd	1.0 mg Pb 0.1 mg Cd	0
Colour - whiteness	not defined	not defined	over 50%	over 65 %

### III. FINAL NOTE

Production of tableware contributes positively to the development of national economies of developing and the least developed countries as it exploits local raw materials, improves employment and enables to reduce import.

The quality control tests are very important from this aspect since they enable to stabilize the properties of products.

The presented paper was elaborated by the UNIDO-Czechoslovakia Joint Programme on the basis of the request of Messrs. TIRDO, Tanzania to assist the developing and least developed countries in this field.

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