Go back to the definition using a source (like a platinum blackbody)

instead of the spectral responsivity of the human eye

Definition of 1967:

The candela is the luminous intensity, in the perpendicular direction,
of a surface of 1 / 600 000 square metre
of a black body at the temperature of freezing platinum
under a pressure of 101 325 newtons per square metre

Definition of 1948:

The value of **the candela** (new candle) is such that **the brightness of the full radiator at the temperature of solidification of platinum is 60 candelas per square centimetre**

Platinum blackbody

In 1881 Violle proposed as a light standard a **surface of platinum at** its **freezing point**

In 1908 Waidner and Burgess suggested as a standard of light a **blackbody**, immersed in a **bath of freezing platinum**

In 1931 Wensel *et al* **realized** the suggestion of Waidner and Burgess – developed a **platinum fixed-point blackbody** where the cavity was immersed in freezing platinum

In 1931 the Wensel’s **platinum blackbody** was adopted as a photometric primary standard by the CCE

Platinum blackbody. Original paper

C. W. Waidner and G.K. Burgess. **1908**

SEPTEMBER 19, 1908. ELECTRICAL WORLD. 625

Note on the Primary Standard of Light.

BY C. W. WAIDNER AND G. K. BURGESS.

CONCLUSION.

Since further work on the Violle standard is contemplated, the authors would suggest that simultaneous experiments be carried out on the black-body platinum standard, as very little additional equipment is required. There is no *a priori* reason why this standard should not be at least as reproducible as that of Violle and it possesses additional theoretical advantages. *The unit of light*, based on this standard, might be defined as the *intensity of the light (white or monochromatic) emitted by 1 sq. cm of a black-body at the temperature of solidification of platinum.* The conditions under which the standard should be constructed for reproducing this unit, such as the dimensions and material of which the black body is constructed, its depth of immersion and other factors, must be carefully specified.

"…the authors would suggest that experiments be carried out on the black-body platinum standard…"

"The unit of light, based on this standard, might be defined as the intensity of the light emitted by 1 sq. cm of a black-body at the temperature of solidification of platinum".

Platinum blackbody. Original paper

H. T. Wensel, Wm. F. Roeser, L. E. Barbrow, and F. R. Caldwell. **1931**

THE WAIDNER-BURGESS STANDARD OF LIGHT

By H. T. Wensel, Wm. F. Roeser, L. E. Barbrow, and F. R. Caldwell

ABSTRACT

A source of light sufficiently reproducible to serve as a fundamental photometric reference standard has been obtained by carrying out the original suggestion of Waidner and Burgess to immerse a hollow inclosure in a bath of molten platinum and to make observations during the period of freezing.

The platinum, of exceptionally high purity, was contained in thorium oxide crucibles and was heated by means of a high-frequency induction furnace. The brightness of the source, reproducible to 0.1 per cent, was 58.84 international candles per square centimeter.

The platinum used was not appreciably contaminated by being melted and frozen over 100 times in crucibles of fused thorium oxide. Various tests indicated that the platinum was at all times purer than 99.997 per cent.

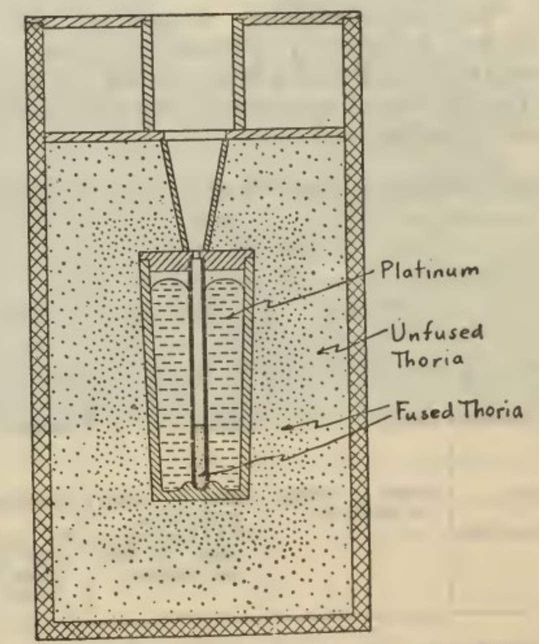


FIGURE 1.—*Cross section showing the platinum crucible and insulation*

WASHINGTON, March 5, 1931.

Bureau of Standards Journal of Research [Vol. 6

Platinum blackbody. Original paper

COMITÉ INTERNATIONAL

DES POIDS ET MESURES.

PROCÈS-VERBAUX

DES SÉANCES.

DEUXIÈME SÉRIE. — TOME XIV.

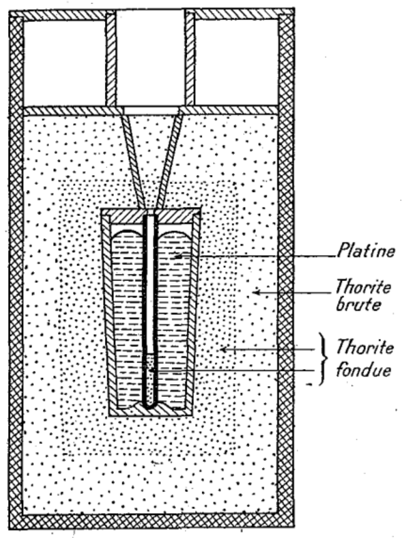
SESSION DE 1931.

PROPOSITIONS

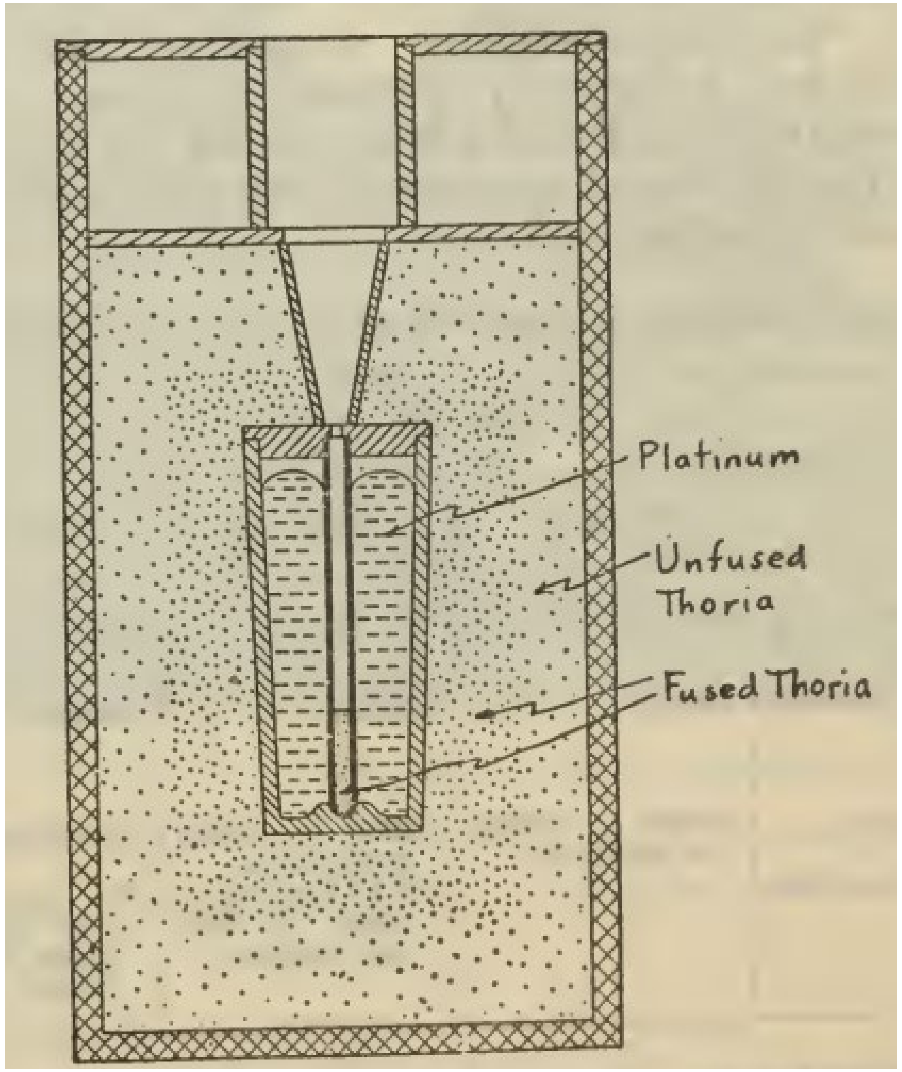
CONCERNANT L'ÉTALON PRIMAIRE DE LUMIERE,

Soumises au Comité consultatif d'Électricité,
institué par le Comité international des Poids et Mesures;

Par M. George BURGESS,
Directeur du Bureau of Standards.

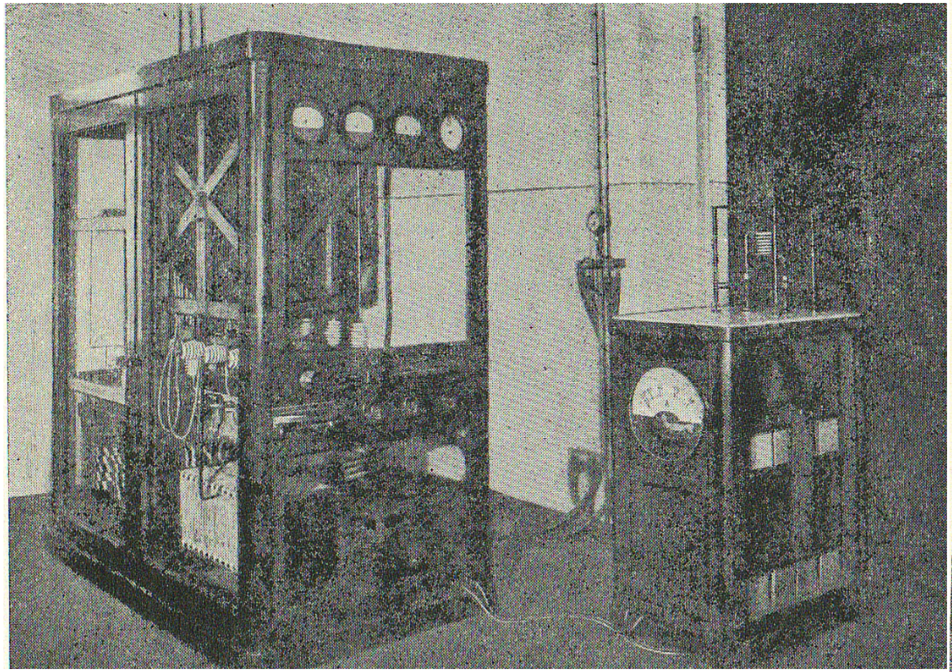


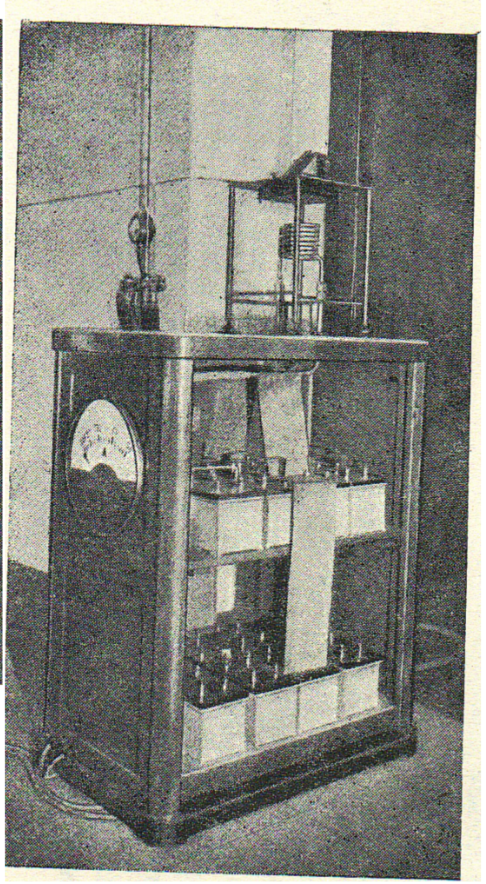
Platinum blackbody. Design

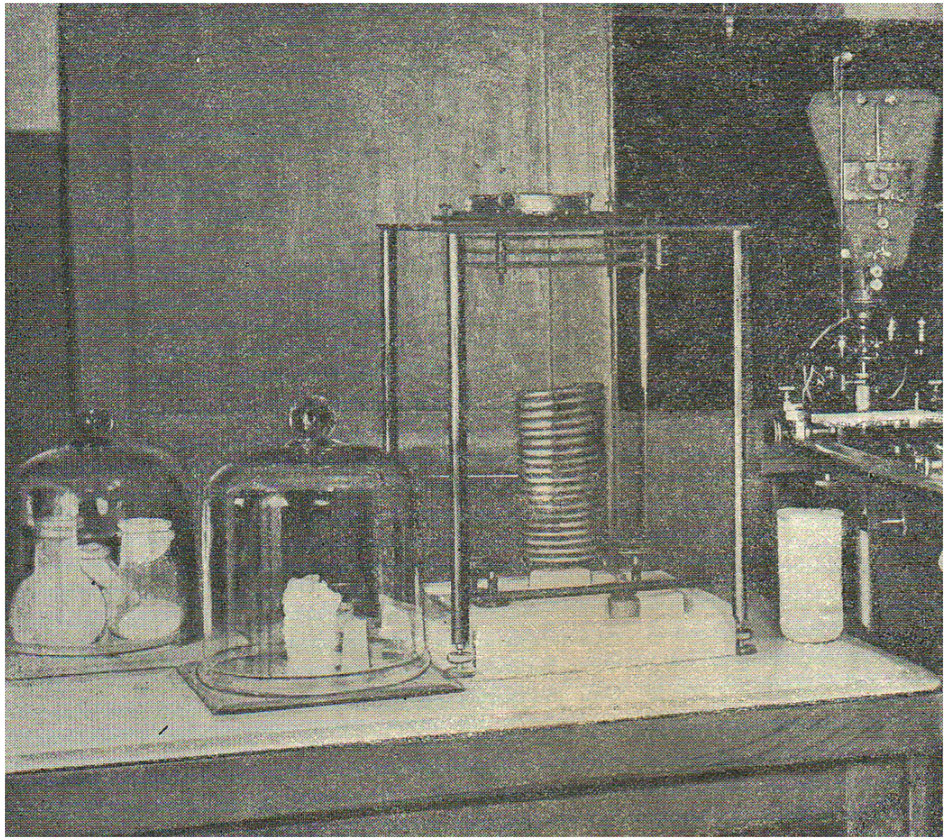


Platinum purity ………... 99.998
Crucible material ………. Thorium oxide (fused)
Heat insulation …………. Thorium oxide (powder)
Crucible length ………..... 45 mm
Crucible outer diameter … 17 – 22 mm
Cavity diameter …………. 2.5 mm
Opening diameter ……….. 1.5 mm
Temperature ……………... 2041.3 K (ITS-90)
Brightness ……………….. 60 cd cm^{-2}

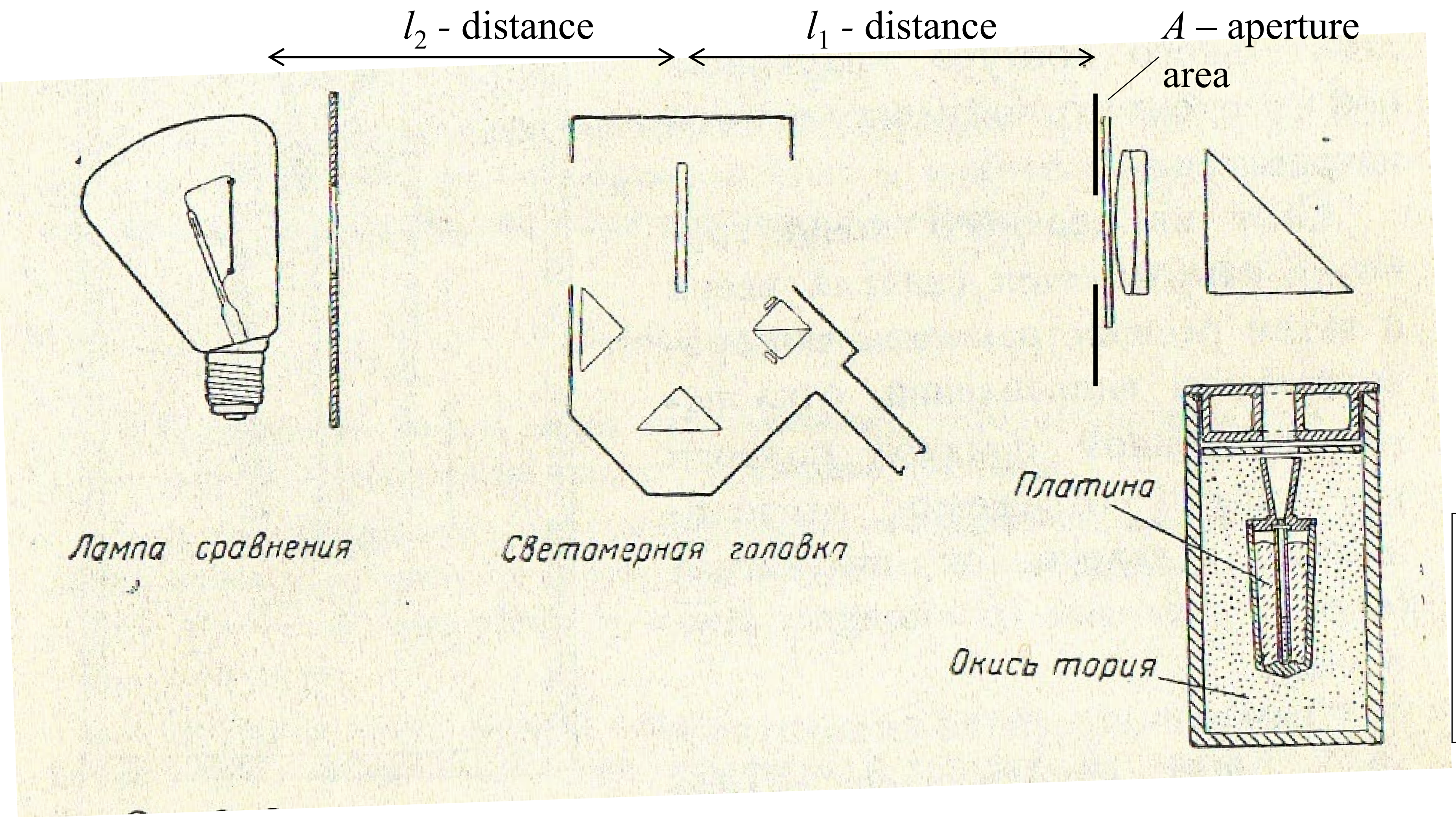
Platinum blackbody. Induction furnace







Platinum blackbody. Realization of Candela



$$E_{\mathrm{v,BB}} = \frac{B_{\mathrm{v,BB}} \cdot A \cdot \tau}{{l_1}^2}$$

$B_{\mathrm{v,BB}}$ - brightness of the blackbody

τ - transmittance of the prism and lens

$$I_{\mathrm{v,lamp}} = E_{\mathrm{v,BB}} \cdot {l_2}^2$$

Cavity diameter ……. 2.5 mm

Opening diameter ….. 1.5 mm

Brightness ………….. 60 cd cm^{-2}

Platinum blackbody

Advantages:

- Chemically stable (platinum did not react with thorium oxide)
- Highly reproducible. 0.1 % - Wensel's estimation

Disadvantages :

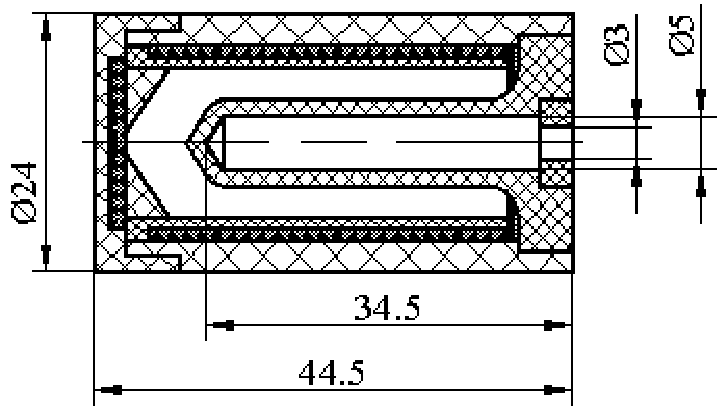
- Temperature (2042 K) was too low for photometry;
- Blackbody opening (1.5 mm) was too small. Luminous intensity could not be realised by the blackbody itself.
- Emissivity of thorium oxide is too low;
- The crucible material, thorium oxide, is breakable
- Thorium oxide is radioactive!

High-temperature fixed points (HTFPs)

***Mise en pratique* – kelvin**

annex “Relative primary radiometric thermometry”

HTFP	Thermodynamic temperature (poi) / K	Uncertainty (poi) (k = 2) / K
Co-C	1597.39	0.13
Pt-C	2011.43	0.18
Re-C	2747.84	0.35

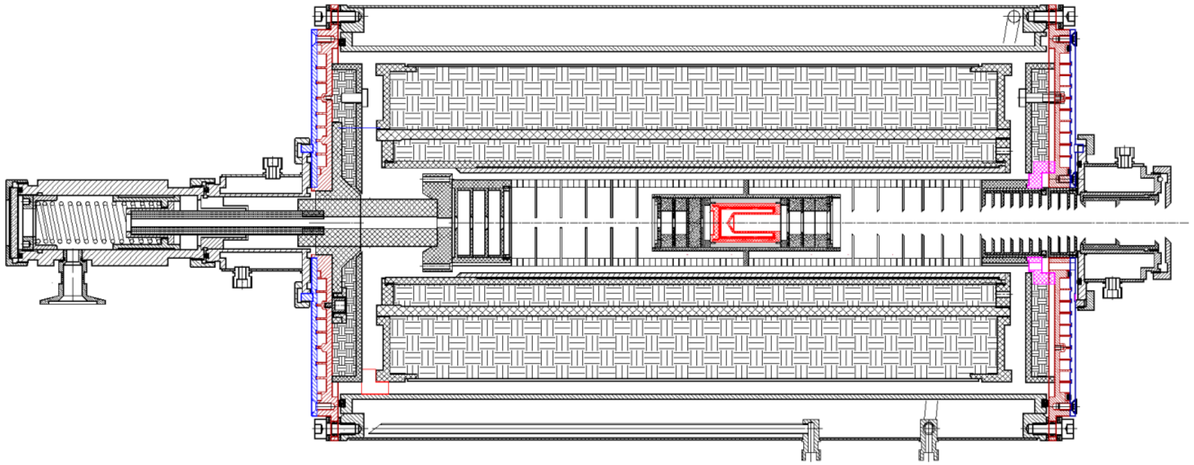


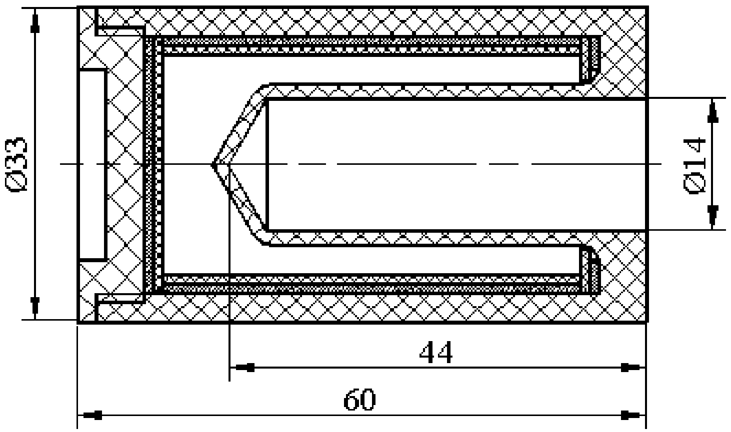
Re-C (2748 K)

δ(MoC)-C (2856 K)

WC-C (3021 K)

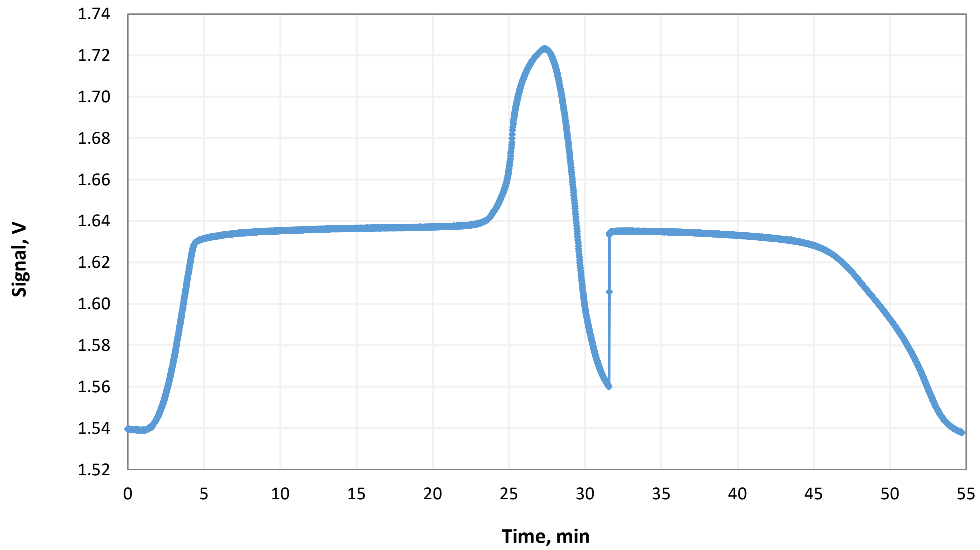
Molybdenum-carbon fixed points blackbody

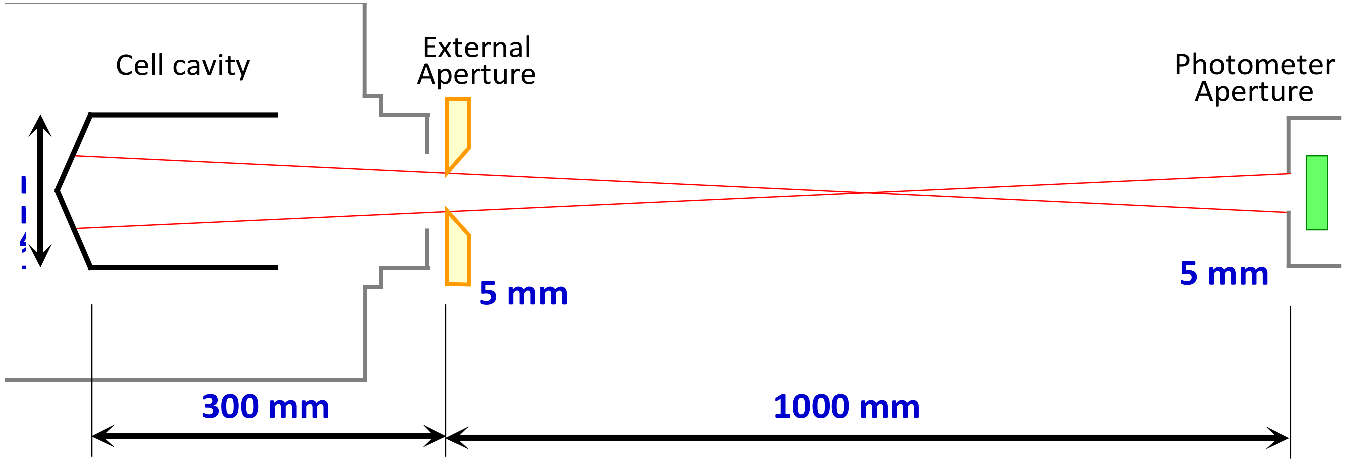


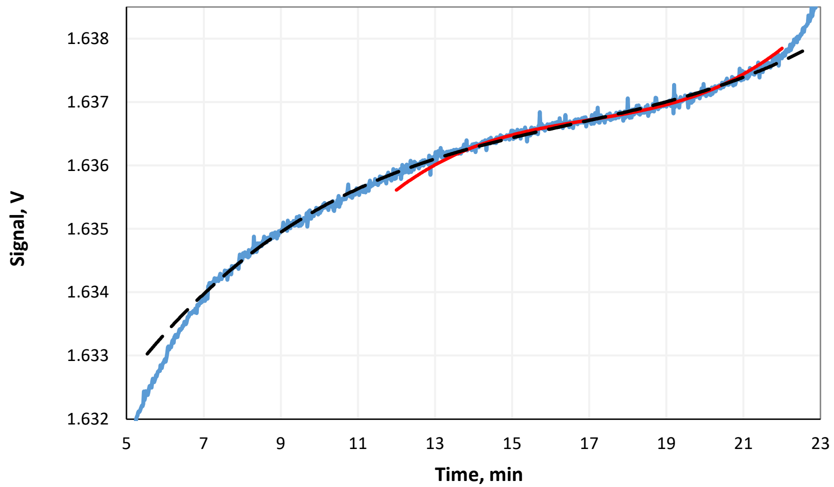


Temperature ……………... 2856.67 K , u_c = 0.23 K
Cavity opening ……………. 14 mm
Crucible material …………… graphite
Emissivity ………………..…. 0.9997
External aperture ………..….. 5 mm
Luminous intensity ………..... 389 cd
Uncertainty of
candela realization ………… 0.20 % (*k*=2)
Reproducibility (repeatability) … < 0.01 %
Long-term stability ……….. 0.02 %

Molybdenum-carbon fixed points blackbody







New Old Definition of the Candela

Now we could go back to the 1967 definition, but replace the platinum blackbody with the molybdenum-carbon blackbody:

"The ***candela*** is the luminous intensity, in the perpendicular direction, of a surface of **5.0432·10^{-8}** square metre of a black body at the **temperature of the molybdenum-carbon fixed point** under a pressure of 101 325 newtons per square metre"

or

"The ***candela*** is defined by taking the fixed numerical value of the **brightness** of a molybdenum-carbon fixed point black body to be **1.983·10^{7}** candelas per square metre

New Old *Definition of the Candela*

"The ***candela*** is the luminous intensity, in the perpendicular direction, of a surface of **5.0432·10⁻⁸** square metre of a black body at the **temperature of the molybdenum-carbon fixed point** under a pressure of 101 325 newtons per square metre"	**or**	"The ***candela*** is defined by taking the fixed numerical value of the **brightness** of a molybdenum-carbon fixed point black body to be **1.983·10⁷** candelas per square metre

Benefits of this definition

The Candela can be realised using the definition only!

(the present definition, 2019, does not allowed this)

New Old Definition of the Candela

"The ***candela*** is the luminous intensity, in the perpendicular direction, of a surface of **5.0432·10^{-8}** square metre of a black body at the **temperature of the molybdenum-carbon fixed point** under a pressure of 101 325 newtons per square metre"	**or**	"The ***candela*** is defined by taking the fixed numerical value of the **brightness** of a molybdenum-carbon fixed point black body to be **1.983·10^{7}** candelas per square metre

Problems

Taking this definition, we **fix the exact value of the** Brightness (**Temperature**) of the fixed point.

This is **a conflict** with the **kelvin definition** in SI

Therefore, we cannot fix the temperature or brightness

New Old Definition of the Candela

What can we do with the Problem? **Avoid Fixed points** in the definition?

"The ***candela*** is the luminous intensity, in the perpendicular direction, of a surface of ~~**5.0432·10⁻⁸**~~ **5.0454·10⁻⁸** square metre of a black body at the **temperature of** ~~**the molybdenum-carbon fixed point**~~ **2856 K** under a pressure of 101 325 newtons per square metre"

In practice, the blackbody temperature $T \neq 2856$ K. In this case we will calculate luminous intensity as

$$I_{\mathrm{v}} = A \cdot K_{\mathrm{cd}} \int \frac{2hc^2}{n^2\lambda^5} \frac{V(\lambda)}{\exp\left(\frac{hc}{n\lambda kT}\right) - 1} \mathrm{d}\lambda$$

Blackbody-based Definition of the Candela

Why not **include V(λ) in the definition**?

"The ***candela*** is the luminous intensity, in the perpendicular direction, of a black body at the temperature of T and of the area A, where T and A are related by the equation

$$1\ \mathrm{cd} = \frac{A \cdot K_{\mathrm{cd}}}{V_{\mathrm{x}}(\lambda_a)} \int \frac{2hc^2}{n^2\lambda^5} \frac{V_{\mathrm{x}}(\lambda)}{\exp\left(\frac{hc}{n\lambda kT}\right) - 1} \mathrm{d}\lambda$$

where n is the refractive index of air, $V_{\mathrm{x}}(\lambda)$ – is one of the CIE spectral luminous efficiency function, $\lambda_a = 555{,}017$ nm and K_{cd} is luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, equals to 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr $\mathrm{kg}^{-1}\ \mathrm{m}^{-2}\ \mathrm{s}^{3}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{\mathrm{Cs}}$".

ВНИИОФИ

Thank you for your attention

Source-based Definition of the Candela

Why not **include V(λ) in the definition**?

"The ***candela***, symbol cd, is the SI unit of luminous intensity of a light source in a the given direction. It is defined by taking the luminous intensity of the source to be equal

$$I_{\mathrm{v,x}} = \frac{K_{\mathrm{cd}}}{V_{\mathrm{x}}(\lambda_a)} \int I_{\mathrm{e},\lambda}(\lambda) V_{\mathrm{x}}(\lambda) \mathrm{d}\lambda$$

where $V_{\mathrm{x}}(\lambda)$ – is one of the CIE spectral luminous efficiency function, $\lambda_a = 555{,}017$ nm and K_{cd} is luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, equals to 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr kg^{-1} m^{-2} s^{3}, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{\mathrm{Cs}}$".