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GLASSES FOR THE PROTECTION AGAINST IONIZING RADIATION

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ABSTRACT
The influence of ionizing radiation on the glass is described in this work, then it shows that roentgen or c – radiation causes structural changes in the glass, which manifests by colouring the glass and which can be prevented by suitable stabilisation of the glass structure (addition of CeO_2). Pointed is the importance of knowledge of the linear absorption coefficients μ and so called equalising factor G. In what follows, given are the transmission features of three groups of coloured glasses under the impact of X radiation.
Keywords: glass, ionizing radiation, X-ray radiation, absorption coefficient, equalizing factor.

1. INTRODUCTION
While working with roentgen rays a protection is needed. For these purposes a lead apron was used before, to absorb roentgen rays by heavy metals. A protection is necessary also by working with radioactive isotopes, then with strong γ – ray sources. In the area where the radiation is in effect, as isotopic laboratories are, long distance manipulators are used, for what a good view is needed [1]. The protection of such a premise toward outside is realised with the help of thick concrete walls, and thick plates of lead glass are mostly put on the windows for visual contact with inside part of the premise.

2. INFLUENCE OF IONIZING RADIATION ON THE GLASS
By using the safety glasses in roentgen or nuclear technique, it is very important to know their linear absorption coefficients (μ) and so called equalizing factor (G). By the protection with lead glass most important is the quantity of lead in it and, with that, the density of glass (σ) and the thickness of glass plate. In the table 1. shown are these values for some safety glasses [2].
By a known thickness of lead, necessary for certain protection, the thickness of glass plate, giving the same protection against radiation, can be calculated by multiplying with glass equalizing factor.
In the Table 1. are given equalizing factors for three radiation energy levels, then the linear coefficient of absorption (μ) for six safety glasses.

As a difference comparing with glass 1, which is Ca-Na-Silicate glass without lead, there is a high content of Pb by remaining silicate glasses, by which the portion of PbO is in the limits 46,3 to 71,3 mass %. Considering the linear coefficients of absorption μ and equalizing factor G for six safety glasses against energy radiation of 0,2 MeV (roentgen rays), 0,6 MeV (Cerium γ-radiation) or 1,2 MeV (γ-radiation of Co), it is seen that with increasing portion of PbO, and consequently of glass density, it comes too to the increase of the linear absorption coefficient. This tells us that the equalizing factor must drop. By the glass with high lead content, with relatively thin glass plate certain protection can be achieved, which would be achievable only with a greater plate thickness by the glasses with lower lead content.

Table 1. Properties of lead glasses for the protection against ionizing radiation

No.	PbO content in the glass (mas %)	Density, σ (g/cm^3)	A		B		C	
			E=0,2 MeV		E=0,6 MeV (Ce_v – zr.)		E=1,2 MeV (^{60}Co – zr.)	
			μ (cm^{-1})	G	μ (cm^{-1})	G	μ (cm^{-1})	G
1	-	2,52	0,31	32,7	0,20	5,51	0,14	3,97
2	46,3	3,68	1,66	6,09	0,32	3,45	0,19	2,93
3	51,2	3,86	1,89	5,35	0,34	3,24	0,20	2,78
4	55,5	4,08	2,12	4,78	0,36	3,05	0,21	2,65
5	64,0	4,60	2,67	3,79	0,42	2,66	0,24	2,33
6	71,3	5,13	3,24	3,12	0,47	2,36	0,26	2,14

Where: σ- density, E– radiation energy, G– equalizing factor, μ- linear absorption coefficient

Comparing the linear absorption coefficients (μ) of some glasses for various radiations, case A, B or C, demonstrates that absorption effect decrease with the radiation energy increase, which is understandable.

On the other hand the fact is not understandable that with the decrease of linear coefficient of same glass its equalizing coefficient decreases too. It is expectable that, aiming certain protection, a smaller absorption coefficient use to be compensated by a greater glass thickness, respectively by a greater equalizing factor.

As a result of roentgen or γ- radiation, structural changes appear in the glass, which cause electrons detachment and rupture of chemical links. It is manifested by colouring the glass, which goes from yellow to dark brown. In the case the glasses are not stabilised against such colorations, after a short time they would become dark brown, not transparent and useless [4].

The stabilisation is enabled by an addition of 1 to 2 mass % of CeO_2 . Its work is based on the fact that Ce^{4+} ions do accept the electrons and are reduced to Ce^{3+}.

Ce^{3+} ions work in photo sensitive glasses as the electrons donors and with the ions of silver they condition photo sensitivity.

$$Ce^{3+} + h\nu \xrightarrow{uv} Ce^{4+} + e^- \qquad (1)$$

$$Ag^+ + e^- \longrightarrow Ag^0 \qquad (2)$$

Ce^{4+} ions work in protection glasses as the electron acceptors:

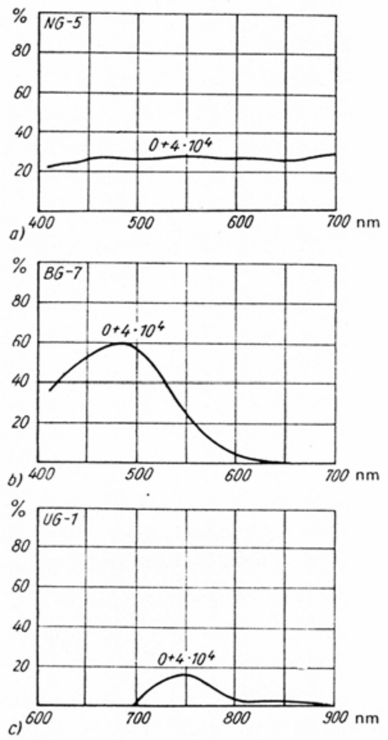
$$Ce^{4+} + e^- \longrightarrow Ce^{3+} \qquad (3)$$

In this way it comes to an important stabilisation and prevention of colouring.

CeO_2 addition leads to a stabilisation in all ordinary optical glasses, which consequently are called "optical glasses resistant to radiation". Such a stabilization is necessary by building in the optical systems in the devices for atomic – physics or atomic – technical researches [5].

By not stabilized glasses the radiation dose of $2{,}58\cdot10^{-4}$ C kg^{-1} leads to a visible coloration, and the dose of $2{,}58\cdot10^{-2}$ to $2{,}58\cdot10^{-4}$ C kg^{-1} causes a strong darkening so that they are no more usable. By optical glasses stabilized with an addition of 1 to 2 mass % of CeO_2 visible colouring appears until the radiation dose of $2{,}58\cdot10^{-1}$ C kg^{-1}. Stabilization work of CeO_2 ions is based on catching the electrons freed by energetic radiation from Ce^{4+} ions, with own reduction in Ce^{3+}. If Ce^{4+} ion is absent, it comes to a partial reduction of importantly more resistant ions, by which the permeability is reduced. Phosphate glasses radiated by γ-rays are coloured less intensively, what is explained by P^{5+} ions reduction to elementary red phosphor. The colour will disappear again if such glass is treated with strongly oxidizing smoke emitting HNO_3 .

3. CHANGE OF PERMEABILITY OF COLOURED GLASSES UNDER THE IMPACT OF γ-RADIATION



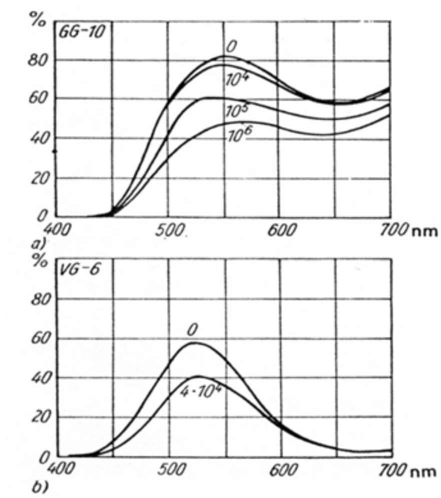
Already in the year 1958, M. Fanderling has examined the impact of γ-radiation, in the range of doses from 0 to $2{,}58 \cdot 10^{-1}$ C kg^{-1}, on the curves of the permeability non ferrous metals. The result of his examination is knowledge whether, by an exposure of the coloured glasses to γ rays, abnormal transmission features of certain glasses can be achieved, which eventually could not be obtained by a normal glass smelting.

In accord with Fanderliks' results, and considering the impact of γ radiation on their permeability, the coloured glasses are divided in three groups:

Group A: Coloured glasses not sensible on the radiation range from 0 do $1{,}032 \cdot 10^{-2}$ C kg^{-1} and not showing a change of permeability. To this group belong all coloured glasses containing Cu, Fe, Co and Ni.

On the Figure 1. shown are permeability curves of Schott's coloured glasses, type NG 5 (boron – silicate glass with addition of Fe/Co), BG 7 (silicate glass with addition of Cu) and UG 1(silicate glass with addition of Ni) in not radiated and radiated glass. It can be certainly stated that there is no change of permeability in the range of χ- radiation doses from 0 to $1{,}03 \cdot 10^{-2}$ C kg^{-1} .

Figure 1. Permeability curves of Schott's coloured glasses for filters NG 5, BG 7 and UG 1 (a-c), which are not sensible on the impact of γ-radiation dose from 0 to $10{,}32 \cdot 10^{-3}$ C kg^{-1} (0 to $4 \cdot 10^4$ r).



Group B: Coloured glasses sensible on the radiation range from 0 do $1{,}03 \cdot 10^{-2}$ C kg^{-1}, by which the permeability is importantly changed in visible part of spectrum. To this group belong, first of all, coloured glasses containing Cr.

As it can be seen from Figure 2., the exposure to γ-radiation leads to an important change of permeability, what is the result of a small change of valence. This effect is used for developing the dosimeter glasses for quantitative measuring the γ- radiation dose.

Figure 2. Permeability curves for Schott's glasses for filters GG 10 and VG 6 (a–b), which, experienced strong changes, after being exposed to γ-radiation (doses from 0 to $2{,}58 \cdot 10^{-1}$ C kg^{-1}, respectively 0 to 10^6r.

Influence on permeability curve can be established if some Cr is added to the glass which is not sensible and contains Cu. Filter glass GG 10 is a silicate one doted with Cr, while VG 6 is boron – silicate glass doted with Cr and Cu.

Group C: Coloured glasses, mainly those with vertical sill or the glasses with subsequently developed colour, of which the vertical sill toward short wave range is not sensible and by the χ- radiation to $2{,}58 \cdot 10^{-1}$ C kg^{-1}, and their permeability curve decrease in all visible range of spectrum, analogous to graduated neutral glasses. To this group belong the glasses with subsequently developed colour of which vertical absorption sill is conditioned by micro waves of cadmium – halogenated.

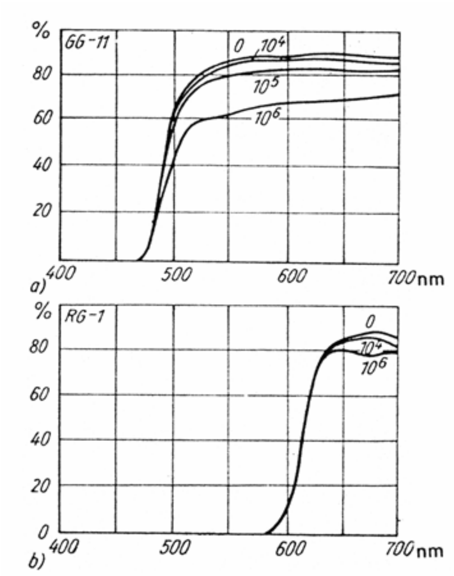


Figure 3. Permeability curves for Schott's glasses for filters GG 11 and RG 1 (a – b) which, after being exposed to γ-radiation (dozes from 0 to $2{,}58\cdot10^{-1}$ C kg^{-1}, respectively 0 to 10^6r), did not experience a change of UV sill, but important changes are noted in horizontal part of the curve.

4. CONCLUSION

By using the lead glasses for ionizing radiation protection (roentgen and atomic technique) most important factor is the quantity of lead in the glass, respectively the glass density, and then the glass plate thickness. Shown is that coloured glasses are classified in three different groups in accord with the influence of X- rays on them, based on the range sensibility of radiation doses.

5. REFERENCES

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