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# The Glass-Selection and Structure-Design of Anti-Radiation Excavator Window

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**Abstract.** In the development of anti-radiation excavator, the structure-design of lead glass windows is a key problem needs to solve. By conducting the irradiation and sun exposure experiment of ZF6 and ZF506 lead glass, we finally decided to use ZF6 lead glass to make the window of anti-radiation excavator. After reading books and conducting experimental research, we decide to increase the thickness of K509 glass at 5 mm on the outer edge of the lead glass's window.

## 1. Introduction

In the process of nuclear industry development, a large number of nuclear facilities and uranium mine will gradually enter the retirement period. In the treating processes of nuclear leak and nuclear facilities decommissioning, it need to have the engineering machinery with function of radiation shielding. On March 11, 2011 in Fukushima nuclear accident [1-2], people tried to use Sany's 62 - metre high, $6 million worth of pump truck to reactor cooling, but finally abandoned for lack of radiation shielding technology and device. Therefore, our research group developed the excavator with the radiation shield cockpit, it can avoid driver been direct exposed to nuclear radiation environment, and it has vital significance to improving the ability of nuclear lead and security of nuclear facilities decommissioning disposal in the country. Structure design of shielding cockpit windows is one of the key issues when developing anti-radiation excavator.

At present, China's nuclear industry use ZF6 lead glass to make shielding windows, but the color caused by ionizing radiation seriously threatening the use of lead glass windows. Lead ionization irradiation coloring refers to the phenomenon which glass (room temperature) get ionizing radiation such as X (γ) rays, neutron generated color heart and lead to visible light is absorbed, is common exist in the multi-component glass ionization irradiation coloring [3-4].

## 2. The Selection Experiments for Anti-Radiation Excavator's Window Glass

The research shows that nuclear shielding window mainly uses the ZF6 lead glass in our country, and storage side of the radioactive material add a layer of K509 irradiation resistant glass. In addition, in order to improve the radiation resistance of lead glass, there are ZF506 lead glass added cerium oxide on the market. In the design of anti-radiation excavator screen window, when we choose which kind of lead glass, and whether to adopt K509 irradiation resistant glass, if adopted this type, how to determine the thickness and such a series of problems, it need to conduct experiments to solve.

### 2.1 The Samples:

ZF6 lead glass, density of 4.78 g/cm3, lead equivalent rate: 0.42 mmPb/mm, size: 50 mm x 50 mm x 60 mm, 2 pieces. ZF506 lead glass, density of 3.86 g/cm3, lead equivalent rate: 0.43 mmPb/mm, size: 50 mm x 50 mm x 60 mm, 2 pieces. K509 irradiation resistant glass, the density of 2.54 g/cm3, lead equivalent rate: 0.22 mmPb/mm, size: 50 mm x 50 mm x 60 mm, 3 pieces.

**2.2 The Purpose:**

Study gamma irradiation and sunlight effect on three kinds of glass's light transmittance, provide the basis for the choice of anti-radiation excavator's window glass.

**2.3 Experimental Apparatus:**

We can use WGT-S transmittance measure/fog tester made by Shanghai instrument physical optics instrument co., LTD, the wavelength range of light measured by meter is: 300 nm to 900 nm.

**2.4 Experiment Method:**

We make irradiation experiment in irradiation center of Hunan province, the source is the activity of 680000 Curie 60Co, ZF6 and ZF506 lead glass samples were placed in the same place, with the silver dichromate reagent measured the dose rate of the place is: 54Gy/h, the two pieces of ZF6 lead glass' placement time is 40 hours and 160 hours respectively, the cumulative dose 2160Gy and 8640Gy respectively, its numbers are 1-40 hzf6 and 1-160 hzf6.The placement time of two pieces of ZF506 lead glass is 40 hours and 160 hours respectively, and the cumulative dose 2160Gy and 8640Gy respectively, its numbers are 2-40 hzf506 and 2-160 hzf506. K509 glass placed dose rate is: 235Gy/h, placing time are 10 hours, 40 hours and 100 hours respectively, cumulative dose is 2350Gy, 9400Gy and 23500Gy respectively, the numbers are 3-10 hk509 3-40 hk509, 3-100 hk509 respectively.

After irradiation experiment measuring the transmittance immediately, and then place the experimental sample outdoor sunlight, light intensity value is about 100000lx, every six hours measure once of the sample's light transmittance.

**2.5 Analysis of Experimental Results**

The transmittance of lead glass 1-40 hzf6 irradiation before was 84.2%, after 40 hours' irradiation, its transmittance was 0.0%. After 100 hours of sunlight the transmittance was 80.5%. The transmittance of lead glass 1-160 hzf6 was 84.7% before irradiation, after 160 hours irradiation, the transmittance was 0.0%. After 100 hours of sunlight the transmittance was 80.8%. The transmittance of lead glass 2-40 hzf506 was 77.3% before irradiation, after 40 hours irradiation, its transmittance was 44.3%. After 100 hours of sunlight, the transmittance was 73.5%. The transmittance of lead glass 2-160 hzf506 was 77.2% before irradiation, after 160 hours irradiation, its transmittance was 7.5%. After 100 hours of sunlight, the transmittance was 68.0%.

According to the experimental data, Transmittance change curves were drawn for four irradiated lead glasses by sunlight exposure in figure 1. The figure 9 shows: under the same dose rate irradiation, the longer the irradiation time of the lead glass, the smaller it's light transmittance. This is because the greater lead glass absorbed the cumulative dose of gamma rays, the higher concentration of color heart is produced. After accept same cumulative dose irradiation, the transmittance of ZF506 lead glass is higher than ZF6 lead glass, so ZF506 lead glass have more resistance to irradiation than ZF6 lead glass. When lead glass after irradiation coloring shined by sunlight, 4 pieces of samples' transmittance were recovered. It can be seen from the figure 9 that the speed of lead glass at the early stages of the sun's transmittance is faster, in the 54 hours' sunlight irradiation time, the transmittance of 1-40hZF6 lead glass go back to 95.9% before irradiation, the transmittance of 1-160hZF6 lead glass recovery to 93.2% before irradiation. The time of sunshine hours range from 54 to 100 hours, the speed of ZF6 lead glass' transmittance recover slower. In the 54 hours' sunlight irradiation time, the transmittance of 2-40hZF506 lead glass come back to 94.7% before irradiation, the transmittance of 2-160hZF506 lead glass recovery to 86.8% before irradiation. From the analysis above, it shows that ZF506 irradiation have more ability of resistance than lead glass ZF6 lead glass, and after shined by sunlight, two kinds of lead glass' transmittance are recovered, but the ZF6 lead glass' recovery transmittance is better. In addition, the transmittance of ZF506 lead glass is lower than ZF6 lead glass before irradiation because of adding the cerium oxide. After the analysis of the experiment results, ZF6 lead glass was chosen to be the windows of anti-radiation excavator.

According to the experimental data, Transmittance change curves were drawn for irradiated K509 glass by sunlight exposure in figure 2. The transmittance of 3-10hK509 glass is 87.3% before irradiation, its transmittance is 86.1% after irradiation, after 100 hours' sunshine the transmittance is 86.0%. The transmittance of 3-40hK509 glass is 87.4% before irradiation, the transmittance is 86.1%

after irradiation, after 100 hours' sunshine the transmittance is 85.8%. The transmittance of 3-100hK509 glass is 87.2% before irradiation, the transmittance is 85.5% after irradiation, after 100 hours' sunshine light, the transmittance is 85.4%. From the experiment above, it indicated that the transmittance of K509 glass' changes is small by irradiation. In addition, K509 glass's transmittance is very high, so we apply K509 glass to radiation protection excavator's windows, because it has little effect on transmittance of window. The literature study shows: on the premise of not hindering the overall design requirements, long-term manned spacecraft in orbit space port can be adds a layer of ionization irradiation in the outermost layer, so as to reduce the amount of ionization irradiation accepted by inner glass, which can decrease the cerium oxide content of the inner layer of glass, to achieve maximum optical transmittance. When the thickness of Quartz glass' against ionizing irradiation layer is greater than 4 mm, 20 years of K9 - HL glass's visible transmittance drop caused by space ionization irradiation damage is very small. The anti-radiation excavator designed by our research group is mainly applied in low-level radioactive environment, the cumulative dose of lead glass during the operation is less than the cumulative dose of space radiation resistant glass in 20 years, so we use K509 glass which thickness is 5mm on anti-radiation excavator windows.

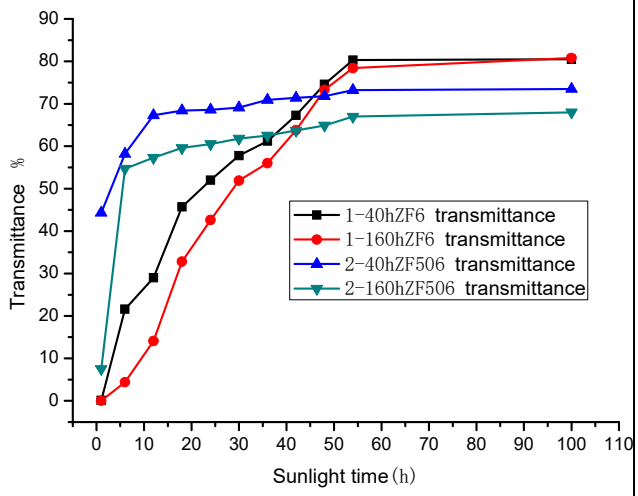


Fig.1 Transmittance change curve of irradiated lead glass by sunlight exposure

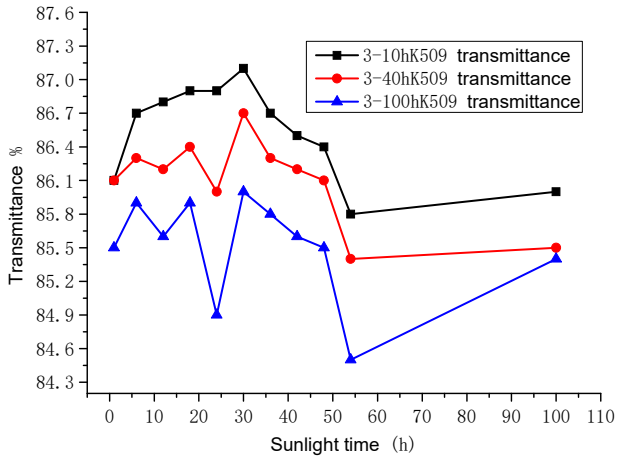


Fig.2 Transmittance change curve of irradiated K509 glass by sunlight exposure

## 3. The Mechanical Performance Experiment of ZF6 Lead Glass

### 3.1 Experimental Samples:

ZF6 lead glass, size is 20 mm × 15 mm ×15 mm, 5 pieces. ZF6 lead glass, the size is 50 mm × 15 mm×15 mm, 5 pieces.

### 3.2 Experimental Purpose

Measuring compression strength and impact toughness of ZF6 lead glass, it can provide the reference for the structural design of anti-radiation excavator's lead glass windows.

### 3.3 Experimental Apparatus:

The compression strength of lead glass is measured in the hydraulic universal material testing machine. Lead glass's impact toughness is measures on a pendulum impact test machine.

### 3.4 Experimental Method:

After the debugging of hydraulic universal material testing machine, we can place a lead glass sample which block size is 20 mm × 15 mm × 15 mm on the measurement of compression strength of work table, starting the machine, pressuring on the sample, until the sample is crushed, then read the reading of the testing machine. Repeat the above process, complete compression strength measurement of five samples, their average is used as the compression strength of glass ZF6 lead.

Check the pendulum impact testing machine, correct zero point. Estimating the damage energy according to the specimen material, to empty the first, measuring the friction's consumption power between the parts. Put up the hammer, and then put the sample into the jaw, and use the model to correct the position with the blade. Setting on the dial indicator needle dial to the left side, preparing the experiment. Pendulum be raised to a horizontal position, then release the pendulum impacting specimen, read the power consumed by the test piece, according to the formula, we can calculate the impact toughness value of materials. Repeat the above process, complete five samples of impact toughness measurement, the average is used as impact toughness values of ZF6 lead glass.

### 3.5 Analysis of Experimental Results

In hydraulic universal material testing machine, we measured compression strength limit of ZF6 lead glass is about 351.75 MPa, measuring the impact toughness on the impact test machine is about 3.22 J/cm2.Compression strength limit of ordinary glass is about 860 MPa, the impact toughness is about 6.62 J/cm2. It can be seen that comparing with common glass, compression strength limit and impact toughness of ZF6 lead glass are low, so in its installation structure design, set up damping spring and damping rubber to meet the demand of the excavator ant-vibration performance.

## 4. The Structure Design of Anti-Radiation Excavator's Window

The anti-radiation excavators developed by the group in the cockpit added a shield outside the original excavator cab, lead glass installed on the outer cockpit, the shielding cockpit has comprehensive protection to the driver. Due to the average height of Chinese men is about 1.7m, make a height of 1.7m person sitting on driving indoor which will be converted to prevent-radiation excavator, first we need to determine the size of an initial lead glass and installation position, use opaque paper to shade the installation location outside of lead glass , make digging bucket at the position such as highest and lowest, most ahead, according to observe effect of observer, we should constantly adjust the size and location of window. Finally, we can confirm that the minimal size of lead glass meets the needs of excavator work lead glass is 400 mm wide, 800 mm high, lead glass' left side is 290 mm wide to the left side edge of the cockpit, the upper is 180 mm to the top of the cockpit. Left the view Angle is 25 º, right view Angle is 31.5 º; overlook angle is 42.75 º, looking up angle is 32.75 º.

## 5. Summary

By studying the influence of ZF6 and ZF506 lead glass's gamma irradiation and sunlight on its light transmittance, we found that the pre-irradiation transmittance of ZF506 lead glass is higher than ZF6 lead glass, in the process of irradiation transmittance of ZF506 lead glass is higher than ZF6 lead glass, the transmittance after sunlight of ZF6 lead glass is higher than ZF506 lead glass. The anti-radiation excavator is easy for outdoor sunlight, so comprehensive consideration of various factors, we finally selected ZF6 lead glass to produce anti-radiation excavator's windows. By reading literature and experimental research, when we design lead glass windows, we need to increase 5 mm thick K509 glass on the outer edge of the glass ZF6 lead glass. This article was funded by Key R & D project of Hunan provincial Science and Technology Department (2015GK3030).

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