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DIRECT VIEWING WINDOWS

by

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SUMMARY

This paper deals with some of the problems of viewing directly into highly radioactive facilities.

It first presents a brief comparison of liquid and solid-glass viewing windows, together with some observations about in-cave lighting, and then goes on to look at experience with windows at Windscale over the last 25 years.

Finally, the direct viewing window is considered in the context of being just one of a number of facets that make up the cave operator station concept.

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INTRODUCTION

1. A direct-viewing window allows the operator of a highly radioactive facility to see into the active area whilst being protected against radiation by the material of the window itself. The protection afforded by the viewing window must be at least as good as that provided by the biological shield wall of the cave. In most cases direct viewing windows are used in conjunction with a pair of Master Slave Manipulators (MSM's). The operator needs to be able to move about to some extent whilst handling the MSM's, and consequently the window needs to have a fairly large aperture. A typical cave window may have an aperture of about 1 metre square.

2. There are two main types of cave viewing window:-

(i) Solid glass

(ii) Liquid

BRIEF COMPARISON OF LIQUID AND SOLID GLASS VIEWING WINDOWS

3. The high density solid glass window has the advantage of being virtually indestructible. One disadvantage of solid glass windows is their inherent yellowness and another is their poor neutron stopping power. What is more, a solid glass window capable of doing the same job as a liquid window can cost up to three times as much.

4. Modern liquid viewing windows are filled with Zinc Bromide solution which is a water-clear liquid of specific gravity 2.5. Properly maintained liquid windows can be virtually water-clear, and hence offer advantages of colour identification and through-the-window colour photography. Because it contains 23% water a liquid window is a good neutron stopper. Because Zinc Bromide volume-for-volume is an order of magnitude cheaper than ceria stabilized solid glass, one can afford to install larger Zinc Bromide filled windows considerably more cheaply than equivalent solid glass windows. One disadvantage of liquid windows is that they are inherently not as safe as solid glass windows because of the possibility of failure if the containment glass was somehow smashed. So far, after 30 years of operating hundreds of liquid windows in the UK such an event has never happened. The foremost practical disadvantage with liquid windows is radiation damage to the Zinc Bromide causing a loss of light transmission. Some poorly-designed liquid windows also suffer chemical contamination and colourful iron pick-up due to the inadequacies and lack of integrity of the glass-reinforced plastic (GRP) containment. The most recently installed liquid windows at Windscale have overcome chemical damage by use of a high-integrity containment box for the Zinc Bromide. Radiation damage can be reduced by placing a thick block of ceria stabilized glass on the hot side to reduce the amount of gamma radiation reaching the Zinc Bromide. Very often this expedient is adopted as a remedy rather than a cure, and is anyhow a costly addition to the liquid window price. One alternative developed at Windscale is to allow the radiation damage to take place (ie omitting a protective glass block), and then, by in-situ recirculation to a small mobile treatment plant, remove the effects of radiation damage chemically. This same plant can also be used to clean up the deleterious effects of chemical contamination through the GRP lining of old and poorly-designed viewing windows.

MEASUREMENT OF LIGHT TRANSMISSION EFFICIENCY

5. Subjective assessment of direct viewing windows is a very uncertain guide

to their behaviour, because no one can carry in their mind's eye the exact intensity of yellow that a particular window exhibited say, six months ago. Recently WNPDL have devised quantitative methods of defining the true colour of a window and its overall light transmission efficiency. Periodic checks with this equipment can detect the beginning of change long before it becomes apparent to the human eye.

IN-CAVE LIGHTING

6. Almost all the viewing in the main PIE caves at Windscale is through liquid windows and the lighting in many of them was very poor. Lighting tests were carried out in caves with new liquid windows using both High Pressure Sodium and Colour-corrected Mercury Vapour in-cave lighting. It was found that both lighting systems were a big step forward when compared with the low pressure monochromatic sodium lighting used hitherto, and problems anticipated with chromatic abberation never materialized.

7. It was found that with a water-clear liquid window the mercury vapour lighting in the cave was uncomfortable to work with: operators said that whilst it was the perfectly matched and colour true light source, subjectively it was too clinically cold to work with. With water-clear liquid windows they preferred the slightly warmer colouring of the HP sodium (daylight) lamps, and the final arrangement was to mount two 400 watt HP lamps in a reflector housing immediately above each viewing window.

8. The inherent yellowness of solid glass windows (even when new) can be offset by using the blue-rich mercury vapour lighting in the cave to effectively synthesise "white" light to the eye. A similar effect can be obtained when operating with a liquid window that has turned yellow in service.

9. In general, one needs to install more in-cave lighting power than is initially required when all the equipment is new. The combined effects of window discolouration, lamp blackening (due to dirt and irradiation), accumulated dirt on reflectors, and fall in lamp luminosity with age all tend to reduce in-cave and as-viewed lighting intensities, and means have to be devised at the design stage to compensate for these effects in advance.

OPERATING EXPERIENCE

Solid glass windows

10. The Windscale experience of large solid glass windows is currently limited to four of the oil-filled variety that look on to a uranium fuel element store cave. These windows were installed in 1960 and have given no trouble and required no maintenance.

11. There are over 100 small solid glass viewing windows built into 4" and 10" thick lead-walled PIE cells at Windscale. These are made from high density stabilized lead glass which is very yellow as installed, and which tends to darken even further with long term irradiation damage. Attempts to recover the glass colour by ultra violet light and by annealing have resulted in only partial success.

Liquid windows

12. There are about 100 large Zinc Bromide windows in service in PIE caves at

Windscale. Almost all of these have been made to an old design that has allowed contamination to penetrate through the thin GRP protective skin on the inside of the liquid containment box. As most of these containment boxes were made from mild steel, over 50 of these old windows now show very definite signs of discolouration due to high iron content in the Zinc Bromide.

13. A development programme to deal chemically with this effect in-situ was initiated about five years ago, and this development has now been successfully brought to fruition. In service, many old and poorly designed liquid windows absorb iron to a level many times greater than that allowed in the Authority Specification which restricts the permissible iron contamination in newly-purchased material to 3 ppm; there are discoloured windows in service at Windscale with over 80 ppm iron. The in-situ chemical treatment process does not remove this iron but rather changes it from the colourful ferric state to a colourless ferrous oxide by reduction.

Containment glass failure

14. Except for a very old liquid viewing window whose history is outlined below, there has been only one containment glass fracture at Windscale, and that was a cold-side bottom corner fracture giving a slow leak.

15. The very old liquid window has failed three times in the last 21 years, and each time it has been a failure of the cold-side glass which in this instance is unusual in being larger than the hot-side containment glass. The basic fault is that the cold-side aperture is extra large and the window glass is not thick enough to prevent significant bowing under the hydrostatic thrust of the Zinc Bromide. In all three instances the failure mode took the form of a horizontal crack right across the glass at a point one third the way up the glass. Once that occurred Zinc Bromide began to leak out, but in each case it took not less than four hours for the Zinc Bromide liquid level to fall to the level of the crack.

16. It is unlikely with a properly designed liquid window that there would be a containment glass stress failure on the hot-side. The correct technique on the hot-side is to incorporate a resin-bond joining the containment glass to the high-integrity GRP liquid containment box. With proper design a hot-side bonded joint can be effected in such a way that it leaves the glass virtually stress free. However the cold-side containment glass is clamped around its periphery onto a PVC (Vybak) gasket, and this is likely to make it the most highly stressed glass in the whole window system. Uneven clamping can create high stress particularly at the corners and this combines with the hydrostatic stress from the Zinc Bromide. Attempts have been made to introduce visual strain gauges in these corner areas to monitor the clamping stress on the glass. Visual strain gauges have now been devised which directly monitor the strain in the glass and some experimental gauges have been attached to three new liquid windows.

Barrier glass failures

17. Barrier glass failures are common to both liquid and solid-glass direct viewing windows. Bolted clamps set around the periphery of the glass are used to pull the glass onto a PVC gasket and some glass barriers have been fractured by incorrect bolt tightening procedures. Failures of this type tend to arise at the corners of the glass, the fracture forming on a right-angled isosceles triangle having a side length of about 20 cm.

18. Further protection should be provided where viewing windows are particularly vulnerable to impact from heavy in-cave objects. One method that has been adopted is to introduce a strong metal grill to protect the hot-side barrier glass. In some instances an alternative has been to use a portable polycarbonate sheet as a temporary protective cover. Polycarbonate is the material normally used in bus shelters to make them vandal proof, and it darkens relatively slowly under irradiation whilst maintaining its excellent impact strength.

Other modes of window deterioration

19. A few glass windows have failed due to the prolonged effect of high intensity radiation. Electrical stress can be induced in the body of the glass and complex internal fracture results, the cracks appearing to start at some point inside the glass block. To overcome this problem manufacturers are investigating glass mixes that have a higher electrical conductivity hoping that in this way built-up internal electrical stress can be leaked away.

20. One of the strangest cases of deterioration occurred in a liquid window at Windscale in 1979-80 over several months. The Zinc Bromide gradually became strongly orange in colour without there being any indication of cloudiness. A one litre sample of the liquid (still looking strongly orange) was delivered in a clear polythene bottle to the analysis laboratory, but before any tests could be started the liquid in the bottle turned water clear! It was found that the liquid in this particular window was light sensitive. When the sample in its bottle was placed in a dark cupboard the Zinc Bromide reverted to its orange colouring. When an ultra violet lamp was placed in the cupboard the liquid remained clear, and when a sample of the liquid was given this ultra violet treatment and warmed slightly it effected a permanent cure. The method of treating the window itself was to add a 500 gram charge of Hydroxylamine Hydrochloride which clearned the window overnight.

THE CAVE OPERATOR STATION

21. A direct viewing window should always be regarded as just one component that has to be carefully integrated into the overall design of an operator station. The basic components of an operator station are:-

- (i) Viewing window
- (ii) In-cave lighting
- (iii) Master-Slave Manipulators
- (iv) In-cave work bench (height)

22. The trend on viewing windows is towards the greater reliability of solid glass despite its poor neutron stopping power. Most newly-installed lighting systems use the HP sodium (daylight) lamps but the advantages of mercury vapour lamps in conjunction with solid glass windows does not appear to have been sufficiently appreciated. The trend in MSM's is towards drop-arm manipulators (ie where the slave arm can be disconnected when damaged and a new slave unit fitted remotely). Despite the cost, the so-called "electrically-separated" MSM's (where Master and Slave units have an electrical rather than a mechanical linkage) are beginning to be considered for future highly radioactive facilities. If and when this form of MSM finds general application the concept of the operator station will suffer a radical change. In theory with electrically-separated MSM's the operator can be in another building or at the other end of the site, and still be able to operate the slave unit effectively; but he would have to rely on a good three dimensional closed-circuit television system which has yet to be fully developed.

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