CVMA NEWS LETTER 11

British Technical Committee, Corpus Vitrearum Medii Aevi

Department of Physics, University of York 1 November 1974 Ref. TC/74/7

CONTENTS

1 GENERAL

1.1 OUR NEW FORMAT

Our pleasant new format has been designed by Mr Peter Winskill of the Printing Unit of the University of York. It gives the News Letters more permanent value and it costs no more than the old format, thanks to the satisfactory arrangements made with the University of York.

1.2 RADIATION MONITORING: NEW EXPERIMENTS

Report YG/74/2 described the successful way by which medieval glass can be distinguished from clever modern replacements by using standard radiation monitoring films to detect the natural radioactivity of the potassium which is present in the early glass. At that time there were two slight difficulties:- (a) control films had to be placed somewhere in order to measure the background radiation in the cathedral and (b) the films were not waterproof and had to be placed on the inside of the windows whereas it might sometimes be more convenient to place them on the outside of the window (for example on the West Porch of Canterbury Cathedral). With the kind permission of the Dean and Chapter, some experiments were started at York Minster on 2nd October using specially constructed films, fastened back-to-back with a layer of Perspex in between and wrapped in polythene. These should be waterproof and, because the Perspex will absorb the beta radiation from the glass, the outer film will automatically provide the control.

1.3 THE EFFECT OF AIRBRASIVE CLEANING ON THE DURABILITY OF THE GLASS

Suggestions have been made (see also Reference No. 171 in Section 5 below) that glass which has had the crust removed by cleaning will possess a lower durability than the uncleaned glass, and that (if true) this might apply particularly to cleaning with the airbrasive. An experiment has been put in hand to learn whether this suggestion is correct.

1.4 VISIT BY DR ERNST BACHER TO BRITAIN

Dr Ernst Bacher, of the Institut für Österreichische Kunstforschung des Bundesdenkmalamtes, recently visited Britain, and he has kindly sent the following note about his impressions:

"On the invitation of the British Council, I had the opportunity in June 1974 of studying the problems of preservation and conservation of a number of prominent examples of medieval painted glass in England and of visiting the stained glass restoration workshops of G. King and Son Ltd in Norwich, the Cathedral Stained Glass Restoration Centre in Canterbury, the York Glaziers Trust, the Camphill Museum in Glasgow (the Burrell Collection), the Victoria and Albert Museum and the laboratories of the British Glass Industry Research Association in Sheffield.

"The overriding impression of the state of preservation of medieval painted glass in England is that where corrosion phenomena occur these are much more serious and have progressed further than is the case in Austria. The destruction of the glass by pitting, with craters breaking up the material, is not found only in England (see for example the west windows of Chartres or the panels from St Walpurgis), but it really does not seem to be so widespread or to have reached so advanced a stage anywhere else.
(RGN - as regards pitting, compared with crusting of Austrian glass, see Collongues and Perez y Jorba, item 171 of Section 5.)
As might be expected, it is the painted glass of the high medieval period which is primarily affected, while glasses of the late 15th and in particular the 16th Century (e.g. King's College, Cambridge) seem to be more resistant and consequently better preserved, probably because of the difference in composition.
In this connection it was interesting to find in the tiny Parish Church of Kirby Wharfe in Yorkshire a small set of Austrian painted glass panels of the early 15th Century, which was probably taken from the collection of Lord Londesborough in about 1860. This glass does not show the specific 'English weathering' but displays the form of corrosion common in Austria, namely a laminar, partly crust-like, partly powdery breaking up of the glass surface. It has now been exposed for about 100 years to the same climate and external conditions as, say, the painted glass of York Minster. Examples of this kind can sometimes provide valuable pointers for research into the causes of the weathering of medieval painted glass, indicating the roles of glass composition, special climatic conditions, etc. (RGN - A study of the composition of the weathering crust, and the chemical composition of the Kirby Wharfe glass, will shortly be carried out with the aid of a special grant from the Pilgrim Trust.)

"There is considerable, and apparently increasing, interest in methods of conservation and preservation. In collaboration with the Council for Places of Worship, the British Technical Committee of the CVMA and various other institutions, all the glass restoration workshops mentioned earlier, some old-established, some newly set up, are co-operatively engaged in finding ways and means of dealing with the extremely difficult problems confronting them. Here too, the basic concerns are increasingly the preservation of the material as such and prophylactic measures which will make it possible to wait until methods, ways and means are found of overcoming the process of decay without putting the material at risk and without deliberately altering the aesthetic appearance.

"This hope is based on the basic research which has progressed by leaps and bounds in recent years, England being an important centre for such research (BGIRA and the Department of Physics of York University). In this connection mention must also be made of the series of experiments being carried out at the present time at the laboratories of BGIRA to investigate the climatic conditions of external protective glazing. These experiments are particularly important in view of the fact that, in my opinion, for a long time far too little attention has been paid to this point, which is of considerable significance for the effectiveness of this method of protection. The results of these investigations will thus be useful both for existing protective glazing systems and for all future projects of this kind. The aesthetic question of external protective glazing as such, a constant subject of discussion, is naturally quite distinct from this. Obviously it does not represent a general cure for all our problems, not only because it must ultimately remain a prophylactic measure but also because it has its limitations and is not always suitable. But in cases where protective glazing can be installed without difficulty it will certainly remain a useful method of conservation until such time as a better method is found which will enable us to preserve the material itself without the risk of any irreversible interference with it."
(RGN - see Item 3.)

1.5 THE "NEWTON BIBLIOGRAPHY"

There seems to have been some misunderstanding about what I mean by "my bibliography", because two have recently been published under my name. The complete version is 93 pages long, it was published for the British Academy by Oxford University Press and it also contains three research papers. These research papers are concerned with ultrasonic cleaning, the recovery of lost inscriptions, and the early work on the "Isoprobe". It can be obtained through any bookseller at a cost of £4 (ISBN 0 19 725947 2). Another, much shorter (46 pages) version was published in Volume 10, No.2 (Winter 1973) of Art and Archaeology Technical Abstracts. The numbers of these abstracts are quite different from those in the British Academy volume, and the latter should be obtained by all workers in the field of conservation of stained glass.

1.6 LASERS FOR CLEANING OF GLASS?

I am indebted to Professor O.S. Heavens, of the University of York, for the following comment.

For some time past, lasers have been available giving sufficient power to vaporise any known material. Commercially-made instruments are to be had for cutting, welding, for trimming resistors or the balance wheels of watches, and a host of other applications where material needs to be removed. The question arises therefore as to whether lasers are likely to be useful for the removal of deposits and encrustations on ancient glass and whether this could be done without damage to the underlying glass. In the event of an encouraging answer to the above questions, a supplementary question arises as to whether we could afford to use such a process if it were in fact developed. In many instances where lasers have been tried for processes which could be carried out in other (more traditional) ways, the novelty of using lasers has been paid for through vastly greater costs - frequently by a factor of ten or more over the normal figures. The laser's real forte tends to be for things which could not be done in any other way or for which clear advantages (e.g. of speed) exist for the laser vis-à-vis existing methods.

The most likely candidate for laser cleaning would be one in which the surface deposit possessed strong absorption bands in a spectral region in which the underlying glass was virtually transparent. In such a case, the laser radiation (assuming that a sufficiently powerful instrument were available for the spectral region in question) will be selectively absorbed by the coating, will ablate it, and leave the underlying glass unaffected except for some conduction of heat. This is similar to the removal of dental caries from a tooth by the ruby laser. The white enamel scatters the radiation but does not absorb it; the brown carious regions selectively absorb the red radiation and the material is volatilised, leaving the underlying enamel unaffected.

In the case of a roughened surface, where leaching or other actions have left a powdery, or skeletonised layer, not necessarily different in absorbing properties from the glass, the effect of laser radiation, in a region where there is some absorption, may well be selectively to ablate the roughened layer. This could arise through the diminished thermal conductivity of such a layer as compared with the bulk material. The loose structure would give rise to considerable scattering from particle to particle. The high thermal impedance could result in a rise in temperature of the particles sufficient to cause volatilization. The conditions are likely to be much more critical in this case than in the absorbing layer situation.

If rapid, selective ablation of coatings is to be effected, it is likely that the coating temperature would need to be raised to a temperature of the order of 1500°K. This indicates a pulsed laser, either in the normal mode (which typically produces a pulse of the order of 1-2 millisecond duration) or in the Q-switched mode (where the pulse length may be of the order of 30-100 nanoseconds). The Q-switched mode provides the higher power density - easily into the tens of megawatts per cm^2 and may subject the underlying glass to smaller thermal stresses compared with the normal mode laser. However, the energy output in the Q-switched mode of a laser is generally significantly less than that for the normal mode.

In view of the wide variety of types of surface defect observed on old glass, it is not possible to do more than speculate on the most likely laser conditions - pulse energy, pulse duration, wavelength, etc - for successful cleaning. A programme would be required to investigate systematically factors such as those above.

The laser has been used by Asmus, Murphy and Munk to remove encrustations of dirt on marble, stone and terracotta with a high degree of success. The results may be of significance for the first-mentioned case above, of glass with a dark, dirty coating. The energy required is estimated at 1-10 joules per cm^2 of surface. Commercial lasers giving pulse of this energy at a repetition rate of 60 per minute are available, so that a cleaning rate of some tens of square centimetres per minute might be attainable. In practice, with glass panes showing highly variable forms of corrosion, it is likely that several shots would be needed at each point, starting at a low power density, in order to safeguard against possible damage to the underlying glass. Moreover, in contrast to the cleaning of a slab of marble or stone, where successive laser spots could be deflected so as to cover the surface with a raster of spots, glass cleaning would entail the careful aiming of the beam at specific features. Thus a more modest estimate of a few square centimetres per minute may be more realistic.

Although detailed costs are not available for the type of system likely to be needed, some indication is given by the following comparison. To achieve the cleaning rate mentioned, a 10-joule per pulse normal mode laser would be required. At 60 pulses per minute, each of duration of the order of 1 millisecond, this represents an average power of 10 kilowatts. The (1972) cost of a 1 kilowatt CW Nd-YAG laser system was £42,000 and the running cost is estimated at about £10 per hour. Although a very different system from the pulsed ruby laser envisioned above, there are sufficient similarities to suggest that the running costs would not be wildly different. Thus even if a careful study of laser cleaning were to show it to be effective, it is likely that the operating costs at present would be prohibitively high.

2 ISOTHERMAL GLAZING: NEW INFORMATION

In News Letter No.10, Item 3.3, it was stated that Mr Ian Addy's drawing of Mr Konrad Vetter's simplified new system for supporting the medieval glass at Berne Minster would be illustrated in News Letter No.11. Part of his drawing I.S/2 is therefore shown in Fig.1 and the strong Anti-Korrodal frame which surrounds the leaded panel can be seen. It is slid upwards into the U-type supports at the sides which will rotate on their pegs in the mullions. It is then allowed to drop into the cup-shaped supports at the bottom corners. Thus both the installation and the removal is remarkably simple.

The space between the two glazings is 22 mm and no direct light can shine around the sides because the frame is 50 mm wider than the medieval glass (25 mm on each side); the medieval glass is supported in the frame by an H-shaped section within the Anti-Korrodal; Mr Ian Addy's report should be consulted for further details, or direct application should be made to Mr Konrad Vetter at Monbijoustrasse, 20, CH Zoll Bern, Switzerland.

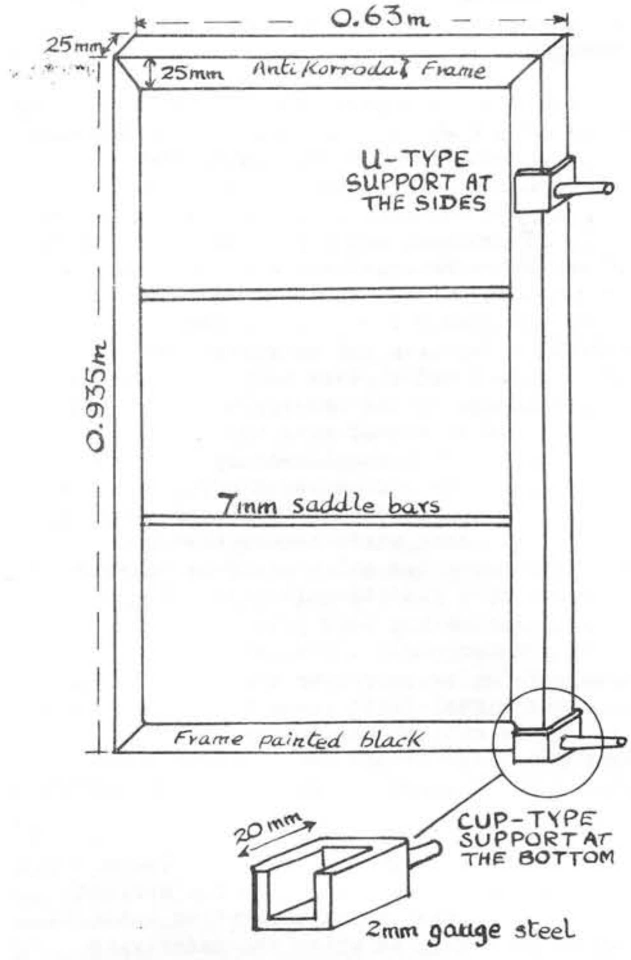

Fig. 1 New Isothermal System at Berne Minster

3 PROTECTIVE EXTERNAL GLAZING: YORK MINSTER

Experiments are in hand to learn something about the humidity régimes which exist in the space between the medieval glass and the modern exterior glazing of the Great East Window at York Minster, and the note in News Letter No.10 about the plated head at Canterbury Cathedral reminded Mr Peter Gibson that he had some photographs which might have a bearing on another aspect of external protective glazing, that of safeguarding the medieval windows from some (at least) of the deteriorating aspects of the weather, and from fouling by pigeon droppings.

The original external protective glazing, erected in the 19th Century, consisted of squares of glass, but these tended to fall out and the glazing was replaced in about 1910 by diamond quarries. These remained in place during the war, the medieval glass being taken down from the inside. In 1952 the external glass was cleaned on the outside. Part of this external protective glazing was removed on 13th July 1970 from the uppermost section of the tracery panels of the Great East Window of York Minster. Because of the close proximity of the medieval glass, the saddle bars were cut with a power-driven circular saw and then removed from the pointing.

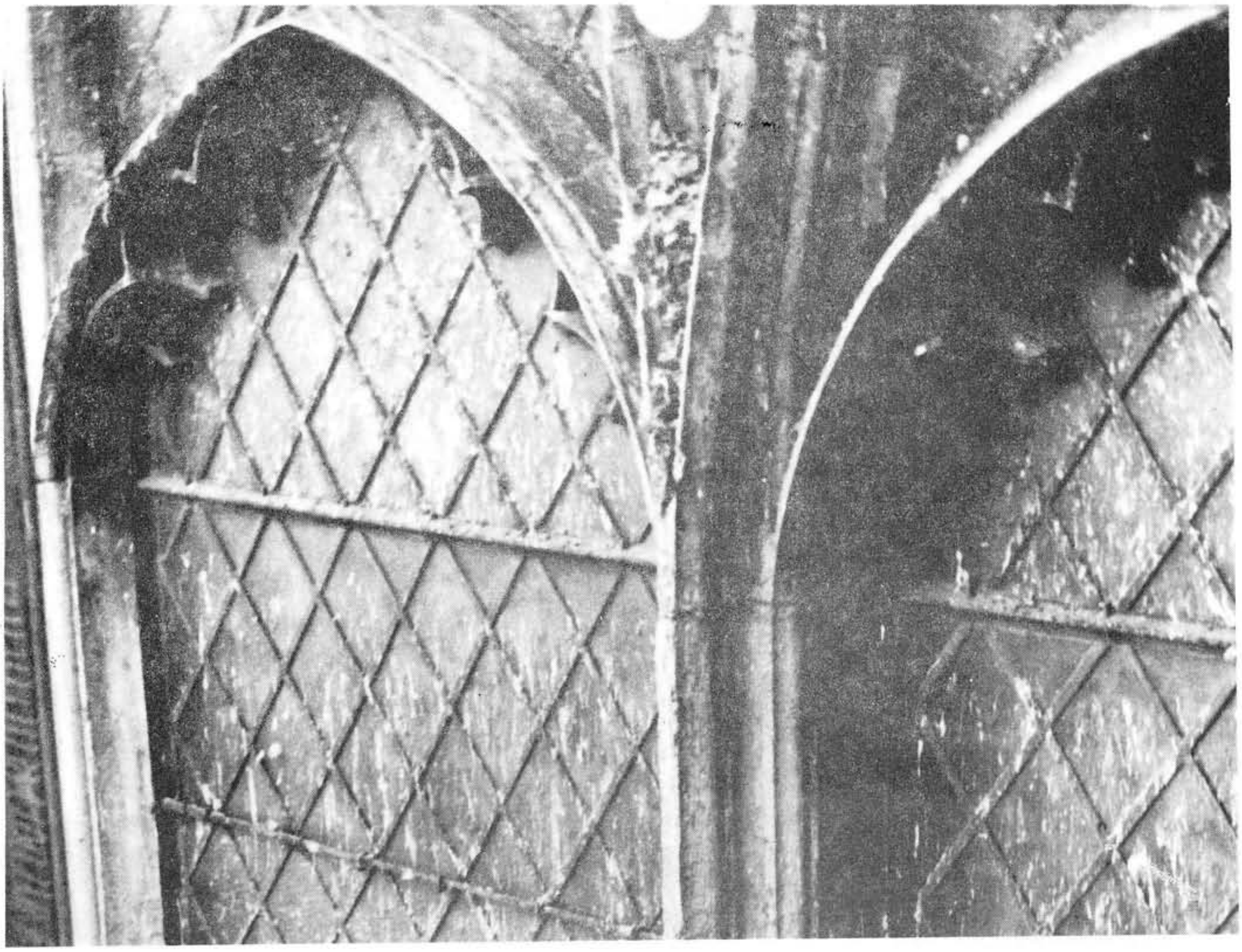

Fig. 2 External glazing of the great east window at York Minster showing the accumulation of dirt and pigeon droppings after 18 years.

Fig.2 shows a view from the outside, the diamond glazing being covered with dirt and pigeon droppings which are evidently not removed by rainfall. It can be seen that the T-bar gives some protection to the window below it, for about half the height of a quarry.

Fig.3 shows one of the panels (on the right) after removal of the external glazing and it can be seen that the glass, and particularly the leading with its soldered joints, are bright and shiny. In comparison the modern glass, and particularly its leading, of the external glazing on the left is dull. Thus 18 years' exposure to the weather since last being cleaned (but nearly 70 years' exposure in all) has caused the leading to become tarnished, and the modern glass to become dulled by the layer of dirt. (RGN - Unfortunately there is no means of knowing whether, and if so by how much, the medieval glass would have been corroded by the weather to a greater extent if it had not been protected. The medieval glass is now not dirty and its leading has not corroded. The collection of dirt on the modern window will surely be a potential trap for moisture which would eventually corrode any glass but we do not yet know how much condensation had occurred on the medieval glass inside the unventilated external glazing and to what extent it could corrode the glass.)

Thus this piece of evidence mainly shows how window glass can become dirty from rainfall, and fouled by bird droppings, and how the leading becomes corroded. We still have to learn how often condensation does occur.

An additional piece of information (for July 1970) is that, based on the cost of the removal of the 13 tracery panels in the upper section of the tracery, it would cost £300 to remove all 161 pieces of tracery from the window.

Fig. 3 The external glazing has been removed from the panel on the right.

4 PHOTOGRAPHIC LIGHT BOX

There has been a problem in standardising the conditions under which stained glass panels are photographed by transmitted light. The light has to be sufficiently bright to enable reasonably short exposures to be taken; the "colour temperature" of the source must be suitable for colour photography; the screen must be substantially uniform in intensity; and it must be able to accommodate the largest panels likely to be photographed. At the request of the York Glaziers Trust a Committee was set up to design a photographic light box and, at the suggestion of Mr A.R. Dufty, CBE, ARIBA, FSA, then Secretary of the Royal Commission for Historic Monuments, the RCHM undertook to construct the box. The Trustees wish to thank him, and his successor Mr R.W. McDowall, OBE, MA, FSA, for all their help in having the box made.

As can be seen from Fig.4, the box is 1.48 m wide and 1.73 m high at the wall side, to which it is fastened. It is raised from the floor, and supported near the front on wooden legs, so that cold air can enter through a shielded slot in the bottom. The air which has been heated by the lamps is extracted to the outside of the building by the extractor fan "C".

The diffusing screen "A" at the front of the box is made from Opal Perspex 6 mm thick and it slopes backwards so that the stained glass panels can rest securely on the supports "B". Thus the depth of the box is 190 mm at the top and 340 mm at the bottom. The illumination is provided by 15 Philips fluorescent tubes, each 1.53 m (5 ft) long, type 65/80W INCFE GRAPHIC A47. All the interior parts are painted white. The luminosity of the screen is 387 lux (36 lumens per sq.foot).

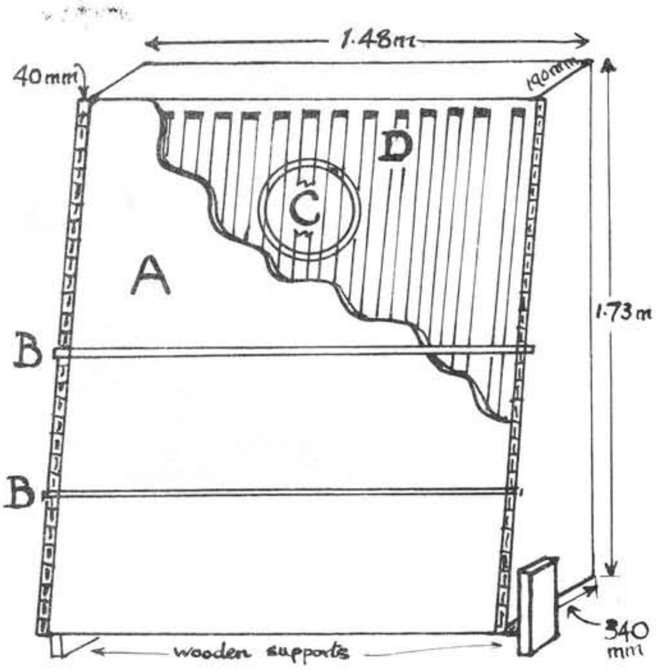

Fig. 4 York Glaziers Trust Photographic Light Box.

Key to Fig. 4

A = Opal Perspex front 6mm thick.

B = Metal supports for stained glass panels, 1.56m long. They hook into the slotted angle iron supports at the sides.

C = Extractor fan (305mm diameter) set in the wall to extract the heated air.

D = 15 Philips 65/80W INCFE GRAPHIC "A" 47 fluorescent tubes each 1.53m (5ft) long.

5 NEW ABSTRACTS

The numbers for these additions to the bibliography continue from those in Section 3 of News Letter No.8.

169. BETTEMBOURG, J.M. (1974) "Le masticage des panneaux de vitraux anciens" (Mastics for ancient glass panels). Laboratoire de Recherche des Monuments Historiques (LRMH). 3 pp and 1 table, 1974.

The author points out that the traditional mastic used for sealing the gap between the flange of the leads and the glass, made from calcium carbonate and linseed oil, has several disadvantages. It will (a) harden gradually so that the leadwork ceases to be supple and the glass may break under wind pressure; (b) shrink so that gaps may form and rain water can penetrate; and (c) mosses and lichens can grow on it. These disadvantages led the LRMH to undertake a study of elastomeric materials which might replace the traditional material.

The test pieces consisted of four glasses of differing thicknesses inserted into the leads and sealed with eleven different mastics (4 were silicones, 2 thiokols, 4 were based on rubber and the eleventh was the traditional mastic). The assembled test-pieces were submitted to 960 hours of cyclical accelerated ageing similar to that used in Ref.8 (Newton Bibliography). The viscosities of the mastics were rather higher than the conventional mastic and some of them were therefore diluted.

Three mastics remained supple after the test period, namely "F" = "SILIGUTT" from Soc. Guttaterna-Séres, 89 rue Victor Hugo, 92-Courbevoie; "J" = "M.S.W.2A" from Soc. Vetter et Fils, 3 rue Christian de Wett, 69609-Villeurbanne; and "K" = "Rhodorsil 3B" from Rhône Poulenc, Avenue Montaigne, Paris 8e. The traditional mastic did not pass the test. Types F and J can be diluted with white spirit to enable them to be brushed under the leads but this dilution does not affect the quality of the mastics. The residue can be cleaned from the glass with a cloth and white spirit and the last traces can be eliminated with vinegar water. (RGN - Does the diluted mastic enter any pits on the surface and, if so, does the solvent remove it from the pits?) Type K cannot be diluted with white spirit and the joints must be filled using a stopping knife, an arduous procedure for large panels.

170. BETTEMBOURG, J.M. (1974) "Protection des verres de vitraux contre les agents atmosphériques. Étude de films de résines synthétiques" (Protection of window glass from atmospheric agents. Study of coatings of synthetic resins). Laboratoire de Recherche des Monuments Historiques. 5 pp of typescript and 3 diagrams, Sept. 1974.

The author remarks that the removal of weathering crusts accelerates the process of corrosion (see Ref.171) and hence freshly-cleaned surfaces must be protected in some way, for example by means of a coating. Twelve resins were therefore tested for their resistance to cold, heat, moisture, U.V. light, SO_2, and permeability to moisture. The 12 resins (4 epoxy, 5 vinyl, 2 acrylic and 1 polyurethane) were first tested on modern glass using the tests described in Ref.8 (of the Newton Bibliography) two lamps being used on this occasion. Nine of the resins failed early, but two epoxy resins (Néocolle and Araldite AY103 hardened with HY956) and the polyurethane (Viacryl VC363 hardened with Desmodur N75) were considered worthy of testing on medieval glass. In this test only the Viacryl VC363 survived for 40 cycles of accelerated weathering and there was excellent adhesion even to the weathering crust.

Samples of the two best resins (Viacryl and Néocolle) were placed in a 300 litre Kesternich oven at 40$\pm$ 2°C in an atmosphere of $1g/m^3$ of SO_2 saturated with water vapour (N.B. this is about 1,000 times more concentrated than a badly-polluted industrial atmosphere) for 8 hours, followed by cooling in air for 6 hours. This 14-hour cycle was repeated 20 times, after which the Viacryl was unaffected but the Néocolle became tacky and yellow after 10 cycles. The Néocolle lost much transparency at all visible wavelengths but the Viacryl 363 remained transparent except in the UV region below 380 mm.

The permeability to water was measured by the amount of alkali (Na + K) extracted from a piece of medieval glass coated with Viacryl 363. The leaching of alkali from the coated glass ceased after 80 hours in a Soxhlet at 80°C, when 0.75 mg had been extracted. The author considers that this extract represents alkaline impurities in the hardened Viacryl film. (RGN - a quick calculation suggests that c. 0.1% of the film had been extracted and his conclusion thus seems reasonable, although it should now be confirmed in other laboratories, especially for longer times at lower temperatures.)

The Viacryl 363 did not chip, turn yellow, lose adhesion or show permeability to water; the resin (80%) and hardener (20%) can be brushed on to the glass after removal from the leads and cleaning (see NL No.7, Item 2.4(b)). It should be noted that Viacryl was used on St Maria am Gestade (see NL No.6, Item 4). It can be removed by dissolving in CITAL. (RGN - in conversation the author pointed out that Viacryl 363 is very good for attaching loose paint because it will easily run under the paint and gives good adhesion.)

171. COLLONGUES, Professor, and Mme PEREZ Y JORBA (1974) "Sur le phénomène de corrosion des vitraux" (On the phenomenon of corrosion of glasses). Ecole Nationale Supérieure de Chimie, Paris, June 1974. 11 pp of typescript and 16 photographs.

This important paper is a fascinating combination of the use of:- (a) the scanning electron microscope (SEM) to examine the surfaces of medieval glass; (b) X-ray diffraction (XRD) to analyse the weathering products; (c) electron microprobe analysis (EMPA) to learn how the weathering products might have been formed; and (d) chemical analysis of the unaltered glass.

Certain types of weathering were found to occur only on glasses having particular chemical compositions. (RGN - this seems to me to be a most important advance because he finds the chemical composition of the glass to be the significant characteristic; not its age, nor the colour, nor the place where the glass was exposed.) He divides his 50 glasses into the various categories given below (but the compositions of only seven of the 50 glasses are actually quoted in his Table I).

As regards the weathering products (analysed by XRD) the usual ones are found to be sulphates (gypsum and syngenite) and quartz. No alkali carbonates were found (perhaps they are too soluble to remain) but calcium carbonate was found several times. (RGN - perhaps carbonates are always formed first, and then converted to sulphates, but alkali sulphates are also too soluble to remain.)

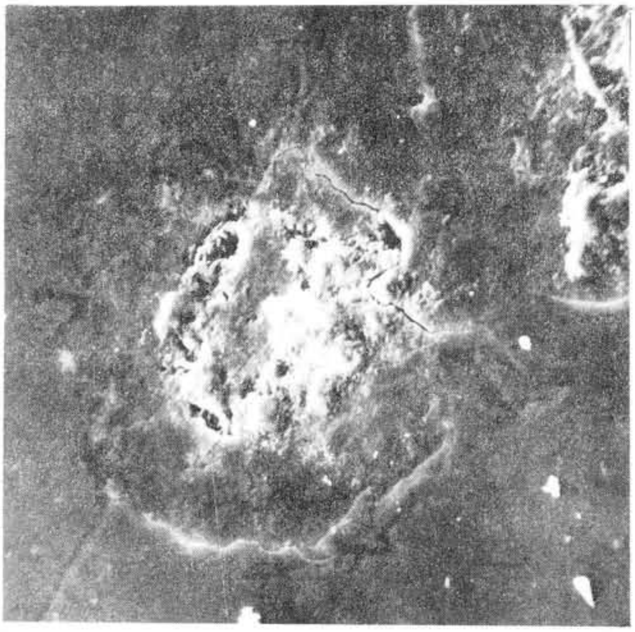

Fig. 5 The early stages of the formation of a pit.

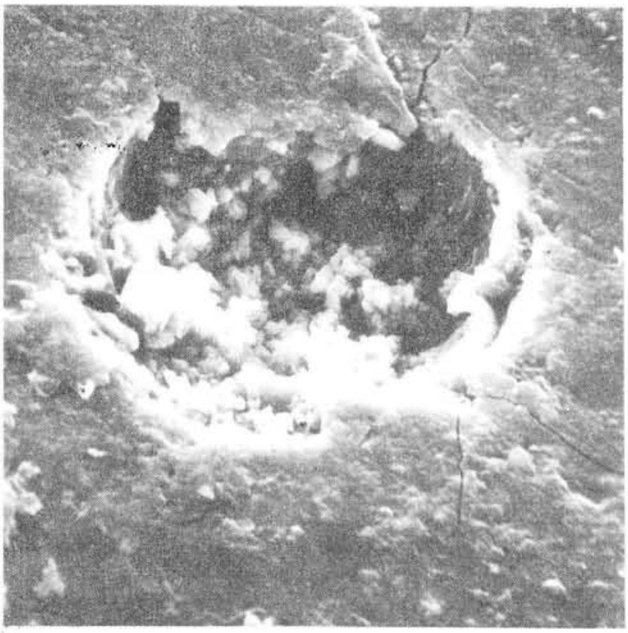

Fig. 6 The inside of a small pit.

The SEM images are quite remarkable for their clarity, and I have Professor Collongues' permission to reproduce two of them. Fig.5 (x330) shows the beginnings of a pit, with apparent signs of solution of the surface around the pit. Fig.6 shows the interior of a small pit (x830); the surface of the glass seems to be raised and there are signs of surface-fracturing. The interior apparently contains crystals of gypsum. For the first time we now know that the walls and bottoms of the larger pits consist of blocks resembling a basalt flow (his Fig.4). The EMPA was used on sections of the glass and shows that calcium migrates from the glass when weathering occurs and sulphur infiltrates the fissures.

I Glasses with less than 15% K_2O and 13-15% CaO. Gypsum is the only weathering product formed (never syngenite) and corrosion occurs by deep pits; these glasses generally contain 4-5% of P_2O_5.

II Glasses with more than 15% K_2O and 11-15% CaO. No pits are formed but, instead, a thick crust of gypsum and syngenite, with the gypsum often occurring in a fine form. He concludes that these "basic" glasses are protected by this crust and any cleaning of the surface (not followed by protective action) will encourage further corrosion. (RGN - It is most interesting to note that Austrian medieval glasses seem rarely to be pitted, and they have high potash contents. For example, the K_2O values (wt.%) are: Lech-kirche 18.1; Mühlkreis 19.5 - 20.3; Heiligenkruez 19.8; Kremsmünster 18.3; Straszengel 21.6; St Leonhard 21.4, etc.)

III "Devitrified" glass with crystallisation of silica. A sample with 12.4% K_2O and 18% CaO has a much sculptured surface with loss of both calcium and potassium; the surface does not contain sulphates and may be rich in silica.

IV Calcite as the weathering product. Nine of the 50 samples show calcium carbonate on the surface and the CaO content varies between 12.4 and 19.7%; there are also unidentified materials on the surface. He concludes that the calcite has a protective role.

V A grisaille window had iron and lead on the surface.

VI A flashed ruby had a network of fractures over the surface and he believes that internal degradation of the glass had occurred.

VII Artificial corrosion of synthetic medieval glasses. Simulated medieval glasses were subjected to damp sulphur dioxide and calcium sulphite was formed on the surface.

Further work will be reported in Professor Collongues' next report and we shall look forward to its appearance with the greatest interest.

172. KAAS, R.L., and KARDOS, J.L. (1971) "The interaction of alkoxy silane coupling agents with silica surfaces". Polymer Eng. and Sci., 1971, 11, 11-18.

This is a paper with a strongly chemical bias but, briefly, the authors have studied various silanes for bonding resins to glass and they conclude that the use of a particular silane (A-1100) in the presence of n-propylamine gives a particularly good bond. The experiments were, however, carried out with high purity silica and the results might be different with glasses which contain alkali, especially early medieval glasses.

173. PALLANT, R.J. (1973) "The response of some leaded windows to simulated sonic bangs". Royal Aircraft Establishment (Farnborough, Hants) Technical Report 73111. 22 pages of typescript and 26 diagrams and photographs.

This is a long and somewhat technical report which studied specially-constructed windows when subjected to artificial sonic bangs, and also the normal window movements in two cathedrals (Truro, Cornwall and St Davids, Wales) over a period of two years. At St Davids, measurements were also made during sonic bangs from overflights by the Concorde aircraft. It was concluded that considerable movements of cathedral windows occur under normal conditions and that the fluctuations caused by sonic bangs are less than those caused by strong winds and gales. If damage were to be caused to a leaded window, the "bang" would have to be 20 times greater than that produced by cruising supersonic transport aircraft. Unleaded glass windows are likely to suffer damage twice as readily as lead windows.

174. SPITZER-ARONSON, Mme Martha. "La distribution du cuivre dans les verres rouges des vitraux médiévaux" (The distribution of copper in medieval red glass). 4 pages of typescript from the Laboratoire de Physique Corpusculaire of the Collège de France, 11 Place Marcellin Berthelot, Paris 5e.

This is a highly specialised study made of various flashed copper ruby glasses, from Amiens (13c), Le Mans (13c) and Lyons (15c). The conclusion was that copper could exist in the glass in two forms, colourless cupric ions which could diffuse in the glass and metallic copper which gave the colloidal red colour and did not diffuse. Anyone wanting more details should consult Dr Spitzer-Aronson.

NOTES