8th COLLOQUIUM of

THE CORPUS VITREARUM MEDII AEVI

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The three earlier highly-personalised annotated bibliographies have been assembled into one document for the benefit of participants and are attached under this cover:-

Items 1 to 26 - prepared for the Cathedral Architects' Conference held 13th to 15th April 1972

Items 27 to 49 - Supplement No. 1, dated 22.5.72

Items 50 to 70 - Supplement No. 2, " 21.8.72

(No newer material has been incorporated)

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These notes are based partly on my own experiences of the problems of weathering of ancient glasses (Newton - 1969, 1971, 1972) and partly on a provisional scan of the literature which has been abstracted in the following pages. The abstracts are highly "personalised" in order to draw attention to problems of conservation but I hope they are reasonably informative about the other information in the papers reviewed. Supplementary bibliographies will be prepared and hence the abstracts have been numbered to facilitate ease of cross-reference.

1. Deterioration of stained glass

From a chemical point of view, the current theory of corrosion is that glass deteriorates when it is kept wet because the alkali ions (sodium and potassium) diffuse out of the glass into the water. They make the water alkaline and this alkaline solution can then attack the silica network of the glass, breaking it down. To preserve electrical neutrality in the glass, the missing alkali ions are replaced by hydrogen ions and, eventually, the surface of the glass becomes a "hydrogen-glass" (instead of a soda-glass); this looks just like a soda glass but its coefficient of expansion is different and the surface would be spoiled when it is heated. If glass is washed regularly the alkaline solution is removed and deterioration is extremely slow; if the alkaline solution is kept in situ (as for example in double glazing where the seal is broken) the deterioration can be remarkably rapid. Different glasses corrode at different rates, depending upon both the alkali and lime contents. A satisfactory soda content would be about 14% but 20% alkali would make the glass rather poorly durable and 28% alkali would make it deteriorate rapidly, especially if the lime content is low. The ideal lime content seems to be about 10% and a marked increase or decrease can have serious consequences. These statements are an oversimplification because potash has a similar effect to soda, and magnesia or alumina have a similar effect to that of lime.

The physical mechanism of actual weathering is exceedingly complicated and much of it is not yet understood. Some glasses form a layered crust at the rate of about one layer per year but apparently not as a result of annual cyclic changes in the environment (Newton - 1971; a possible mechanism for this cyclic behaviour is discussed on pages 7 and 8 thereof). There is a marked tendency for the attack to be extremely local, not only forming hemispherical pits (which might be accounted for) but also forming "plugs" (see Fig. 5 on p. 151 of Brill and Moll - 1961 and Figs 1 and 3 of Newton - 1971) which are not at all understood. Another baffling problem is how the painted design on the inside of a stained glass window succeeds in influencing the pattern of corrosion on the outside of the window.

Some glasses do not weather in this layered manner even though adjacent, apparently similar, pieces may deteriorate badly (see Newton - 1969). The reason is not yet known but Professor Douglas recently carried out a small study of the matter and it seems likely that there is an optimum lime content for good durability; a moderate excess of lime makes the glass much worse. Much more effort should however be made available in the interests of long-term preservation of stained glass.

2. Cleaning of stained glass

Regular washing with water may be sufficient to prevent deterioration because the corrosive alkaline deposits are then removed, but strongly alkaline cleaning solutions are dangerous and "Flash" is said to have damaged the decoration on some windows in Wales. It would seem that the pH value should not exceed 9. Some cleaning treatments involve hydrofluoric acid, but these should not be used on the insides of stained glass windows (or where paint or stain is present). The hard opaque deposits may have to be ground away, and the surface repolished in order to produce any light transmission at all. Scientific work is clearly needed on the physical and chemical nature of these coatings.

3. Restoration

The renewal of lost or damaged painting is in the province of art-historians rather than glass technologists but there are practical problems which require solving. Often the painting seems more durable than the glass, and the design gradually becomes raised; here it may be possible merely to use ultrasonic probes to remove corrosion products. But if the paint is less durable it can leave a reflective mark on the glass and then re-painting would be needed preferably by using a durable "cold" paint rather than refiring with its risk of damage, although much old glass has been refired without apparent damage. Sometimes the refired paint does not "wet" the original glass and the surface-tension phenomena should be studied scientifically.

4. Consolidation

Araldite resins seem to be satisfactory for cementing broken fragments edge-to-edge. "Plating" has its adherents provided that the air gap is sufficiently ventilated to avoid condensation of moisture.

When glasses develop the layered structure the crust becomes porous; it seems that the transparency might be restored by impregnating the porous layer with a "resin" having a suitable refractive index but such an impregnant should be easily extractable. Opinions are divided on which "resin" should be used, or even whether any "treatment" is likely to be harmful.

5. Preservation

Many materials have been recommended for preserving the cleaned glass against further attack and this is a field where more scientific work is needed. There are problems associated with the "insolubilisation" of plastics materials which occur with ultra-violet light, and claims made (eg. Elizabeth Jones, 1963) that such cross-linked resins can be "re-formed" by chemical treatment. Lamination procedures are being used at Cologne Cathedral but most of the evidence is "hear-say" and there is a fear that organic acids may form in the laminates over long periods of time. I have tried to make "helpful" comments in my abstracts of the papers on the following pages but I have deliberately been cautious rather than optimistic where the "permanence" of organic materials is involved.

1. BIMSON, M and WERNER, A. E. (1964). "The danger of heating glass objects", J. Glass Studies VI 148-150.

The authors comment that a conservation technique for stained glass, recommended by Domaslowski and Kwiatowski (1963), involves heating the glass to a temperature of 225-235°C and they describe an instance where the gentle heating up (to only 90°C reached over a period of eight hours) of a 17th century wheel-cut goblet cover caused serious surface crazing. They also demonstrate that incipient crystallisation of the glass was not present. The Editor of J. Glass Studies added a footnote that the Corning Museum of Glass had had similar experiences and an experiment was carried out where 23 samples of ancient glasses had been heated (first to 110°C for 60 hours and then to 175°C for 160 hours) and seven of them were damaged by this treatment. The reviewer had some correspondence with Dr. Brill in November 1971 about the problem and the concensus of opinion is that glasses which have formed a "hydrated layer" (the surface layers have been transformed into a hydrogen-glass) are liable to show this surface damage on mild heating (or even without any heating).

2. BRILL, R. H. (1970). "Scientific studies of stained glass - A progress report", J. Glass Studies XII 185-192.

This preliminary report on chemical analyses of stained glass windows vindicates the supposition that they may have chemical compositions which are characteristic of the period or of the place of manufacture. But the reviewer considers that such analyses could be of even greater interest to the conservator because glasses with poor durability should have recognisable compositions, such as a high alkali content (more than about 15% $Na_2O + K_2O$) and an alkaline earth ($CaO + MgO$) composition differing markedly from 10% . Thus the 12th and 13th century samples from York Minster would be expected to be more durable than the 14th century ones from Avignon or the 15th century samples from Ulm. It would be interesting to know whether that was actually the case and Dr. Brill's further results will be awaited with much interest.

3. BRILL, R. H. (1971). "A request for help in the conservation of early stained glass windows". Presented at IXth International Congress on Glass, Versailles, 27th September 1971. 12 pages. Unpublished but copies available from The Corning Museum of Glass, Corning New York 14830, USA.

This important paper (all readers of this summary should have a copy) is an appeal for more effort to be devoted to the conservation of medieval stained glass and, in particular, more cooperation between glass technologists and stained-glass conservators. It is stated (without the evidence) that stained glass windows are being damaged by air pollution and urgent action is necessary. The author points out that the effects of deterioration take many diverse forms; the recommended treatments are both diverse and controversial; and there is inadequate background knowledge about the chemical properties of the glasses and the processes which cause them to deteriorate. In addition there is a need to train more conservators.

In the seven-page appendix he sub-divides the problems into:- 1. Cleaning (twelve methods are mentioned briefly); 2. Restoration (the repainting of lost parts and the re-attachment of loose paint; he comments that refiring may have its dangers if the glass is susceptible to damage on reheating - see Bimson and Werner - 1964); 3. Consolidation (plating, laminating, reinforcing and cementing); and 4. Preservation by coatings or treatments (which must be removable without damaging the stained glass; double-glazings must be ventilated or condensation may make the damage worse; removal to museums may in extremis be the only hope). Finally, 21 aspects are listed which require consideration in any cleaning/preservation technique.

4. BRILL, R. H. and MOLL, S. (1961). "The electron-beam probe microanalysis of ancient glass", Recent Advances in Conservation, Butterworths, London, pp 145-151.

This paper is concerned primarily with the electron beam equipment and its possibilities, but part of p. 150 and most of p. 151 is concerned with the weathering crusts on ancient glasses; in particular Fig. 5 shows an enlarged view of a cross-section of corroded glass and it can be seen how the corrosion pits extend deeply into the glass. Table 7 gives the results of analyses of various corrosion products and it can be seen that marked loss of alkali occurs as the result of weathering. (It should not be forgotten that these are "archaeological" glasses in the sense of having been "buried" and it is possible that stained glass windows may weather in a different fashion.)

5. CAVINESS, Mrs. Madeline H (1971). "Report on the conservation of the stained glass of Canterbury Cathedral", unpublished.

This 21-page typescript document is primarily an account of the present condition of the glass at Canterbury Cathedral but there is also much of interest to the conservator. On p. 1 there is an implied suggestion that the glass in the Trinity Chapel has deteriorated noticeably since 1967, and on p. 4 it is stated that cracks in some plated glass were repaired with Lepage's glue some 20 years ago but the glue has deteriorated, moisture has entered the space, and the growth of moulds has occurred. On p. 5 she states that examination of glasses which had been protected by leads show evidence of more corrosion in the period 1850-1890 than had occurred between 1180 and 1850. She also remarks that ancient glass will desiccate and powder in hot dry conditions but this seems to be an over-generalisation. On this page there is also a remark that pigeon droppings may damage the glass (without quoting evidence) as well as obscuring it.

Pages 7-9 discuss modern methods of restoration, especially as regards ultrasonic cleaning and resurfacing of the back. Resurfaced glass which has a poor durability will start to deteriorate again and a case is quoted where a "film" has formed after only ten years. She also claims that any "resins" used to improve transparency must be of a "soluble" variety and hence would be unsuitable for exterior work but the studies of Elizabeth H. Jones (1963) would, if confirmed, open up a different avenue. On p. 8 it is suggested that the sulphate deposits from modern "polluted" atmospheres are more destructive to glass than are carbonates but the evidence is not quoted and there may not be a simple comparison.

Mention is made of re-plating techniques carried out every ten years and (on p. 9) a case is described at All Souls College (? New College ?) Oxford where a plated gap filled with water. Page 10 comments on other ancient glass and it seems that Canterbury glass differs from most in possessing extensive back-painting, thus greatly increasing the restoration problem. Pages 11-14 summarise her conclusions and outline some interesting proposals, No. 5 being the collection of environmental data.

6. CVMA. (1970) 7th Conference, Florence 12th-16th October 1970, Technical Committee: Answers to the questionnaire on the discussion on windows, 40 pages in the English translation.

This document records the views of 14 experts (two Austrians, E. Bacher and Eva Frodl-Kraft; three Belgians, A. Calders, J. Helbig, and R. Sneyers; two French, L. Grodecki and J. Taralon; five Germans, R. Bechsman, G. Frenzel, A. Meyer, E. Schürer V. Witzlaben and H. Wentzel; and two Italians, Gilli-Pirina and G. Marchini) on the ten subjects listed below. The replies involved architectural and aesthetic aspects but this abstract concentrates on the aspects of conservation of medieval stained glass windows.

1. Use of external glazing and grills: the former is highly recommended provided there is adequate ventilation between the window and the exterior glazing to avoid condensation. It protects the glass against further atmospheric weathering (if restoration must be delayed), against thermal shock, vandals and sonic bangs; and protection against UV light can be provided if desired. It also protects the lead as well as the glass and prevents cold air from entering the church; interior condensation may be reduced. Differences of opinion exist as to whether the exterior glazing should be a single pane or broken up (eg, into a diamond network) in which case the external pattern may confuse the pattern of the stained glass unless a diffusing screen is also incorporated. Another possibility is individual plating of each piece of the window but this adds to the weight and prevents ventilation of the space. Grills are regarded as superfluous if external glazing is used, unless the window is very valuable and at a low level.

2. Should cracks in the glass be leaded? There was much difference of opinion: five said that leads should be used but only one commented, ie that the original pieces of glass must be recoverable unaffected, and the other four seemed to take the view that adhesives might be objectionable; three were not prepared to comment and the other six considered that leads should not be used because clarity of the design may be lost, the edges of the pieces must be grozed to make room for the lead and the weight of the panel is increased.

3. Should plating be used? There seems to be a general reluctance to plate panels, the technique being regarded as a last resort when the panel is very thin, or badly cracked (spider cracks), or a missing design can be painted on the plating. There is a widespread fear of "synthetic resins" and any adhesives used must be reversible. In one instance it was suggested that the plating should be fused to the old glass in a furnace ("Si des conditions techniques le permettent, le meilleur collage des fragments de verre ancien sur leur support de verre incolore ne consiste-t-il pas en une legère fusion au four?")

4. Cleaning of stained glass is clearly a controversial matter, with ten experts recommending some cleaning and four objecting to any cleaning which alters "the original patina" (RGN's note - what is "patina" in a severely crusted glass?) ie which does more than remove dust, soot, etc. Some who accept the need for cleaning insist that only the outside may be touched. Another suggests that restoration of a window to the "original state" is a completely illusory aim; even if transparency is regained the colours will be paler and the design may be altered. A third takes a different view and states that the passing of the years has created an incomparable ancient beauty. (RGN's note - presumably "better" than the "original"!)

As regards the cleaning agents, those recommended include "Calgon", "Pril", polyphosphoric acid, hydrochloric acid, and volatile solvent material (unstated). Many of the experts appeal for work to be done to develop "more effective and safer cleaning methods". One specifically mentions that hydrofluoric acid must never be used. (RGN's note - It should be remarked that the book "Glass in architecture and decoration" (see Reference No. 19 below) recommends the use of dilute hydrofluoric acid for cleaning glass windows in buildings. For example, on p. 580 it is stated that glass which has been roughened by atmospheric attack "...can only be satisfactorily cleaned by an application of hydrofluoric acid, which in effect acid-polishes the surface and restores its brilliance". Again, on p. 428, "The only infallible way of removing both the dirt and the weathered film is to use hydrofluoric acid. This acid even in low strengths, is able to decompose and dissolve the silicates of which glass is chiefly composed. If used in 1 per cent solution it will clean the dirtiest of glass in a matter of seconds, leaving a brilliant, smooth surface. The glass has in fact been 'acid-polished' by a process which is in common use for brightening the surface of new glassware".)

5. Preservation of loose black paint is another stormy subject! If sufficient design remains, some experts recommend synthetic resins or even an easily-fusible glass which melts at 400°C. If much of the painting has disappeared, one suggestion is to repaint and re-fire or paint a piece of new glass, "contour" it, and plate the old glass.

6. Restorations. Opinion seems to be about equally divided between using only old glass or using suitable modern glass (of the latter, the type "Chutes de Versaille" is especially recommended by one expert),

7. Restoration of a missing pane. Much seems to depend on the instructions from the owner of the glass but there is agreement that replacements must be marked as such.

8. Preservation of the outside against corrosion is a matter on which everyone agrees that more information is needed. The arguments in items 3 and 4 are repeated.

9. Preservation of old leading or not; use of mastic?
10. Reinforcements;
11. Supplementary stabilisation of panels.

The discussions under these items are largely constructional ones but it is evident that there is a strong preference for re-using the original materials wherever possible.

7. CIHA. (1969) (Comité International d'Histoire de l'Art, avec l'aide de la fondation kress.) Bulletin du CIHA, Janvier-Mars-Juin 1969, Colloque de Split. Page 8 has a note "Problêms de la technique et de la restauration".

Page 8 of this document summarises a discussion which was largely occupied with those aspects of the composition and profile of ancient leads which render them superior to modern leads but there was also some discussion of the conservation of stained glass. Eva Frodl-Kraft remarked that the compositions of 13th and 14th century glasses were similar but the 14th century Norman glass was thinner and better-made.

Jean Taralon referred to 13th century grisaille high up in the nave at Evreux which was completely corroded on the external face and he described two attempts which had been made to remove the opaque crust; use of hydrofluoric acid and grinding it away. Both of these were effective but grinding seemed easier to use and was less expensive. G. Frenzel described two systems for cleaning "spoiled" (abîmés) windows; the use of plating with glass or with synthetic materials. The resins which he used (not specified) tended to go yellow but they could be removed without damaging the window; he stressed that his results must be regarded as provisional.

Dennis King spoke of his cleaning methods; washing with pure water (as at King's College, Cambridge) and, only when necessary, grinding very opaque pieces. During the ensuing discussion it was claimed that windows were painted on both sides and grinding must remove the design on the outside. Might the grinding be carried out only as far as the "layer" (couche) of the painting? As regards the replacing of panels, this is done in Austria but in France any ancient pieces removed are stored in a museum. Plating and condensation were also discussed and the Technical Committee was charged with the investigation of all these problems.

8. DOMASLOWSKI, W and KWIATOWSKI, E. (1962) "Probleme der Konservierung von Glasmalereien" (Problems of preserving stained glasses) Ann. 2nd Cong. Journ. Int. du Verre, Leyde, 30 Juin – 4 Juillet, pp 137-151.

They discuss the problems experienced in Poland (at Chelmno, Krakow, Torun and Wloclawek) and stress the damage caused by static water (condensation) contrasted with regular washing which removes the products of deterioration. Their history of methods of conservation is largely quoted from HETTES (1955) q.v. They are rather perfunctory in their comments, dismissing E. FRIEDEL-KROLL'S technique (1955) as having a mixed reception and William LOWE'S (1960) as "not permissible" apparently because he ground the weathering crust away and cleaned out the pits with a dentist's drill; regarding FRENSEL'S work they could not obtain any details. The Dörner Institute's method (1939) – of sticking cover glasses on both sides of the windows – is said to make the windows too thick and heavy; ugly bubbles form in the resin and the cover glasses are virtually impossible to remove. The Swedish patent (No. 113009 – 1944), which used acrylic resins at room temperature, were said not to stick well and the acid cleaning bath (5% HNO_3) was said to destroy the paintings. L. TORWIT'S (1952) protective wax (Propolis) was said to develop an intense brown colour. Silicone resins were said to have been used successfully by the Czech. Acad. of Fine Arts, but no details are given.

In describing their own method (pages 143-147) they say that the looser parts of the weathering crust (consisting of carbonates) must be removed (because they encourage further deterioration) but not by using acids, bases, domestic powders and pastes, or by grinding and drilling; all are harmful because they claim that removal of the hard crust (which must be done mechanically) weakens the glass, exposes the deeper layers to atmospheric attack, alters the colour values of the glass and is aesthetically undesirable if outside decoration may be removed. Instead they use only very gentle treatments to clean, wash, and dry the weathering crust. The film and the painting is "fixed" by means of a diluted solution of plasticised polyvinylacetate (c.f. Max Unwin (1951) for explanation) which has been modified by methyltriethoxy silane in xylene. Such treated glasses are said to need the constant supervision of the conservator so that appropriate measures can be taken should any changes occur! (Apparently the resin can easily be removed at any time – p. 144.)

In order to "harden" the panes, and prevent them from further destruction they use polymethylmethacrylate but they do not use it at room temperature on the grounds that it then shows poor adhesion to the glass, low resistance to water which results in swelling, and low surface hardness. Instead they use higher temperatures and claim that optimum results are achieved when the temperature is just below the depolymerisation temperature, ie 225-235°C (they claim "yet unexplained structural changes in the resin" as conferring special advantages). (Note by RGN: these temperatures seem excessive, even to polymer technologists, and Bimson and Werner (1964) q v. regard such heating of the glass as potentially dangerous.) They claim that, despite fears that cross-linking of the resin may occur, the polymer retains its linear chain structure and also its solubility in suitable solvents. They note that, since their publication in 1956, they have modified their impregnation process and now use a copolymer of methylmethacrylate with methyltrioxysilane (see note 3 on p. 146) and impregnate under reduced pressure (details are also given of other changes in strengths of solutions, etc) and they remark that this method can only be used when the glasses will not crack or crystallise; they claim to test this with X-rays. (Note by RGN: The discussion following the meeting showed that they look for true devitrification (see Newton and Werner 1972) by using X-ray diffraction but it seems highly doubtful that devitrification can occur in cold glass and, as pointed out by Bimson and Werner (1964) q.v. the reverse does not hold good (p. 150, col. 1) and glasses which show no X-ray pattern can be damaged by heating to 90°C.) They also state that it is pointless to use this method for glasses where the crust is not porous.

The last main part of the paper is concerned with sticking together fractured panes. (RGN's note – a number of adhesives seem to be suitable for doing this and apparently there is no great problem but the authors give directions for two methods of handling glass fragments where the broken edges do not fit perfectly (pp. 148-9). Finally (pp. 149-150) they discuss the kinds of records which should be kept during the conservation process. During the discussion following the lecture, Herr Wihr warned that heating of glasses above 45°C involved great dangers (ugly looking scales form, it looks awful and becomes worthless). Also in the discussion, Mme Vassas-Dubuisson remarked that cold glasses do not show the true devitrification which the authors expect to detect with their X-rays and she also warned that polymethylmethacrylate does cross-link and become insoluble, contrary to the authors' claims. (RGN's note – it seems that more comments are required from the polymer technologists, and this will be sought.)

9. FRENZEL, G. (1970, a) "La conservation des vitraux anciens. I. Les causes de degradation - developpement et importance". 5 pages of typescript, undated but probably Sept. 1970.

He starts with a description of medieval stained glass and notes that the design (full lines and half tones) is usually on the inside surface but the modelling may be on the outside surface. However, the amounts applied to each surface may vary from period to period. The leading not only holds the pieces of glass together but also contributes to the aesthetic effect by emphasising the principal parts of the design. During restorations the windows are generally de-leaded and hence instances where the original leading remains are rare and very important: for example, the Apostle Window of the Marienberg Convent at Helmstedt, the window in the south transept of Altenberg Cathedral, and others in the Hesse Museum at Darmstadt.

Glass is not an easy material, not only because it is brittle (can be damaged by storms, vandalism, hail, and jet aircraft) but because it degrades easily. This is particularly true for the glass in Cologne Cathedral, the Church of St. Kunibert in Cologne, and other churches in Naumburg, Erfurt, Munich, Augsburg, Obergaden, Nuremberg, Esslingen, Ulm, Straubing and Iphofen, as well as many parish churches. About a dozen other churches are mentioned where the condition is better; in pre-renaissance churches the windows are in museums (a list is given which is also repeated in Reference No. 11 below) and have been replaced by copies. Some windows remain in districts totally isolated from industry, for example in certain Alpine valleys. The kind of glass used also has a bearing on its durability.

When the corrosion is very advanced the windows become opaque with a covering of carbonates and the inside is also affected by condensation; even windows which appear bright may in reality be severely attacked. In some cases (five are named) the painting has decomposed and can be seen only by reflection (negative decomposition). The painting sometimes leaves clear traces (the Prophets window at Augsburg Cathedral, etc). Sometimes the painting has weathered so badly that it has "eaten" into the base glass to form a "relief engraving" (Erfurt).

Windows which have been spoiled by atmospheric impurities have sulphates in the crust. The end of the process is the destruction of the glass and its replacement by a thick hard deposit of gypsum, called "pierre du temps" or "Wetterstein" which in certain cases is already several millimetres thick (Cologne, Ratisbonne, Augsburg). Far from protecting the glass this deposit activates the process of corrosion.

The first stage of degradation is the separation of horizontal layers (producing iridescence) and this is followed by the development of foci for attack leading to pits and craters in which the corrosion products collect. (Note by RGN: These "foci" undoubtedly exist but I consider that the phenomenon is a haphazard one and I am inclined to doubt his explanation that they originate around "inclusions" such as impurities, unmelted sand grains, air bubbles, etc; see Newton (1971) below. He also remarks that the pits form along irregularities in the painting but this seems almost to be an effect of protection formed by the paint. See also my remarks on the paper by F. Raw (Reference No. 25, below) – end of RGN's note.) In addition to the formation of pits, a network of fissures forms in the surface, at first invisible to the naked eye but developing markedly in the course of time, (perhaps by contraction of a hydrogen-glass surface – RGN). Eventually the glass falls into small pieces (choir of the Church of St. Lorenz at Nuremberg) - (also at Sandringham – RGN). The same sort of thing can also occur on the inside of the windows, but much more slowly. In nearly all cases the painting is also attacked and this can be the end of the work of art. The same thing is to be found everywhere:- Cologne, Chartres, Brussels, Berne, or Vienna.

10. FRENZEL, G. (1970, b) "La conservation des vitraux anciens", four pages of typescript, undated but probably Sept. 1970.

There is no general recipe for cleaning medieval windows and the restorer must use his own judgment with its heavy responsibilities. The term "cleaning" (nettoyage) which he uses does not imply making "absolutely clean" (rendre propre) and even less reconstituting the imagined original state; he is concerned with laying it bare (mise à nu) with a view to fixing and conserving the work.

The progress of corrosion must be halted and the glass must be protected. Before starting, a minute examination must be made of both sides of the window and a record made (macro and micro), and the transmission should be measured; then a decision must be taken as to which parts should be cleared and which not.

(1) Simple chemical tests should be made to identify dusts, oils, greases, atmospheric impurities and, above all, carbonates and sulphates. Liquid solvents which do not attack the glass are available for all of these, eg, acetone, ethyl ether, toluene, "unitral", "coloradol", hydrogen peroxide, and "Calgon". Carbonates can be removed with a solution of ammonium fluoride. After each chemical treatment careful washing must be carried out, preferably with distilled water.

(2) If these solvents are to be used the decision must be that of the restorer, rather than the chemist, several points requiring consideration, (i) the painting must not be endangered (detached paintings are a particular case, see (3) below); (ii) the patina must not be endangered (the changes which occurred during ageing and which characterise each original); (iii) the original image must not be compromised (the results of corrosion which permit important deductions to be made, eg, the "negative corrosion" or the painting on the back). If the crust is removed from the back the original image cannot be reproduced. In regaining transparency by the absence of the back-painting, the painting on the front could become "overexposed". The ideal would be to approximate to the "original state" by stopping "half way" if this can be judged, but the restorer may well not have any training and will find it difficult to know when to stop.

(3) Aesthetic considerations intervene only exceptionally in the decision about cleaning. In general there should be absolutely no cleaning if guisaile might be lost. Cleaning always has some undesirable effects but external protection does not involve a permanent loss and has much to recommend it. When exterior glazing is used care must be taken to avoid condensation, by circulating dry air, use of silica gel or a dehydrating cartridge, or a warm air heater. Alternatively, a reversible anti-corrosion protective measure can be used, such as plating, putting under glass, evaporating a metallic film or using a layer of synthetic resin.

Cleaning must be carried out when dangerous atmospheric contaminants are present. If the painting has become loose, each case presents its own problems. If cleaning and protection is not undertaken the painting will surely disappear in time; if a circumspect cleaning is undertaken a macrophotographic (larger than 1:1 - RGN) copy should be made as a control.

Laying the glass bare, in the sense of removing or dissolving the crust requires tools and materials. The hardness and adhesion of the crust should be tested with probes ("un jeu de pointes de durete"); detached layers should be removed with "glass fibre pincers" of a soft grade ("Weichengrad"); the solvents and white cloths must be obtained. He gives preference to this method before all others, and uses it without exception. The work is very tiring and long-drawn-out, (an average of about two to four weeks per window) and demands much knowledge and experience on the part of the restorer.

11. FRENZEL, G. (1971) "Umweltgefahren bedrohen mittelalterliche Glasmalerei (Environmental dangers threaten medieval stained glass), Kirche u. Kunst, 4 (December) 58-60.

This short article covers similar ground to that in Reference No. 9 above. He also remarks that medieval stained glass is badly deteriorated and the initial stages of decomposition can be observed better on more recent work, such as Renaissance glass, Baroque cabinet panels, or even late-Gothic bulls' eyes and roundels. In connection with corrosion of stained glass he blames sulphur dioxide (RGN- see my notes on Korn's paper, Reference No. 17 below) and states that the sulphuric acid which may form effects a real etching process on the glass ("Schwefelsäure, die auf dem Glasgemälde einen regelrechten Ätzprozesz bewirkt", but acid solutions have much less effect on glass than do alkaline solutions, and all chemists know that sulphuric acid can readily be kept in glass bottles whereas strong alkaline solutions may detach flakes of silica from the surface - end of RGN's note.) A long list of damaged windows is given at the top of p. 59, col. 2 (the same as in Reference No. 9) and a description is given of Korn's case No. 3 (Reference No. 17). He recommends that all important windows should have protective glazing placed on the outside, in place of the old windows, the stained glass being mounted inside (see bottom of page 59). This arrangement can satisfy the structural and aesthetic requirements and eliminates weathering and static condensation, so that further deterioration is significantly retarded. The oldest example of such external glazing (100 years old) is in the church at Lindena in central Germany and the windows are in as good a state as those removed to Nuremberg museum at the same time. Protective glazing was installed in the chancel of St. Sebaldus's church in Nuremberg in 1954 to 1956 but unprotected panes in the body of the church (cleaned at the same time) already have a crust 2 mm thick. Many other examples of protective glazing (in Switzerland and Germany) are quoted, the protective glazings being window glass, safety glass, "Perspex", or made up as a leaded window.

Problems in true conservation are also being tackled by the Institute for Materials Science III of the University of Erlangen-Nuremberg and an atlas of damage is being drawn up in connection with the Air Pollution Section of the Union of German Engineers.

12. HEDVALL, J. A., JAGITSCH, R and OLSON, G. (1951) "Über das Problem der zerstörung antiker Gläser II Mitteilung. "Über die belegung von Glasoberflächen mit Schutzfilmen". (On the problem of the destruction of antique glasses. Part II. On the covering of glass surfaces with protective films.) Trans. Chalmers Inst. Techn. No. 118 (15 pages).

They attribute the decay of ancient glass to the presence of water and carbon dioxide and the leaching process is described, and they inhibit the process by an organic coating. First, the object is de-greased with carbon tetrachloride and cleaned in 5% nitric acid. It is then washed and dried in a vacuum chamber (10^{-6} mm Hg) which is then filled with the lacquer and slowly emptied and drained.

The choice of the lacquer and the solvent is claimed to be important; the viscosity must be right and there must not be too much shrinkage on drying. Polyethylene was regarded as too hydrophobic; the adhesion of polystyrene to the glass was too low; polyvinylchloride formed too soft a film; polyvinylacetate was too permeable to water (but see Reference No. 26); polymethylmethacrylate was regarded as the best material provided the right solvent was used (see also References Nos. 8 and 15); other materials found not satisfactory were butadiene rubbers, melamine resin, alkyd resin, cellulose derivatives and silicone (but see References Nos. 13 and 14). (This process is also the subject of Swedish patent No. 113009 (1944) and further details will be provided in the next supplement to these notes - RGN.)

13. HETTEŠ, Karel. (1955) "O ochrane sklenenych pamatak pres odskelnovanim". (On the protection of old glass objects against "devitrification" - ie weathering, see Reference 23). Zpravy pamatkove pece, Prague 8, XIV, 240-245.

He discusses the deterioration of glass articles and refers to "crystallisation"(but this is wrong, see Reference No. 23). The history of conservation is summarised, from the time of Kunckel (1689) to the work of Rathousky (1955). The latter used a silicone lacquer with "astonishingly good results". The experiments were "not yet finished" but he hoped to preserve the Gothic window in the church of St. Bartholomew in Kolin. (RGN - surely the results must be known by now and enquiries will be made.)

14. JACOBI, R. (1971) "Ein Konservierungsverfahren für mittelalterliche Glasfenster auf der Basis der modernen Sicherheitsglastechnik". (A conservation method for medieval glass windows using a modern safety glass technique.) Glas-Email-Keramo-Technik, May 1971, No. 5, 172-174.

He discusses the fixing of loose black paint with silicone lacquers and the repairing of cracked panes with adhesives but regrets that these simple and effective techniques cannot be used if the windows are very frail. His laminating technique was used at Naumberg Cathedral and the new glass was shaped to the contour of the old glass and then laminated to the inside of the panes by means of an intermediate plastic layer (the composition is not stated, but modern safety glass uses polyvinylbutral - RGN). If the outside is badly attacked, or the medieval glass is very thin, new glass is laminated on the outside also. Fragments can be preserved without the use of leads and the window is made stronger (? and also heavier ? - RGN); the cracks are then hardly noticeable.

On p. 173 he discusses the removal of the weathering crust and states that this can easily be done by using diluted hydrofluorosilicic acid (H_2SiF_6) - not to be confused with hydrofluoric acid (HF) - without in the least affecting the black stain (or patina). For the last 17 years the windows of the chancel of Cologne Cathedral, as well as the windows of St. Kunibert, have been preserved in the same way with good results. It is claimed "with certainty that this type of preservation will maintain the present condition over a long period of time". (Man kann mit Sicherheit annehmen, dasz diese Art der Konservierung den jetzigen originalen Zustand über einen langen Zeitraum unverändert erhalten wird"). (Note by RGN - the makers of modern safety glass for motor cars believe that the windscreens will remain unaltered for 20 or 30 years but some doubt is expressed as to whether some organic acids would be released by the action of UV light. They do not expect cars to last so long, so they are not troubled by this, but further enquiries will be made - end of note by RGN.)

15. JONES, Elizabeth, H. (1961) "The effect of aging and re-forming on the ease of solubility of certain resins", pp 79-83 of Recent Advances in Conservation, Butterworths, London.

This article is concerned with the preservation of oil paintings but it may have relevance to the conservation of stained glass because the author maintains that "resins" which have become insoluble by crosslinking under the action of UV light can be "reformed" and made soluble again by treatment with certain polar liquids. (Note by RGN: her chemical explanations on p. 82 (bottom of col. 2) to P. 83 are distinctly unorthodox but the possibility of "resolubilising" plastics may be worth consideration by the Technical Committee. A recent letter from Miss Jones (25 Feb. 1972) commends polyvinylacetate as being "extraordinarily stable: we have a specimen which was painted out in 1924 which is still colorless, uncracked and quickly soluble in toluene".)

16. KING, Dennis, G. (1971) "Winchester College stained glass. Part II. Technical report on the restoration of the glass". Archaeologia 103, 166-174.

The author refers to the difficulties encountered in restoring glass to which an artificially-produced patina seems to have been applied with some kind of varnish, such as shellac. The aid of the late Professor Harry Moore was sought and he found that nitric acid was effective in removing the applied layer, and much safer than a hydrofluoric-sulphuric acid mixture, even the vapour of which could have damaged the painting. The nitric acid removed a layer somewhat less than 1 mm thick and the glass was then "substantially unaltered and practically as permanent as when it was originally made". The pitted and roughened surface was finally smoothed and polished as is done for optical lenses (details are given on p. 168).

Twenty-one treated specimens were then examined by Professor Moore in 1950 and detailed comments are included in the paper but no satisfactory method was devised for removing the corrosion products from the inside surface without also damaging the painting. One sample (Specimen S) was so inhomogeneous that differential corrosion occurred along the lines of the cords in the glass. (Note by RGN: here is clear evidence of compositional variations influencing the extent of the corrosion, but Professor Moore's comments that pitting may be due to local inhomogeneities may not be valid (see Reference No. 21) – end of note by RGN.) On p. 170 Professor Moore describes the action of moisture, and of alkaline solutions, on glass and points out that any covering or deposit which is not "completely" impermeable to water may increase the extent of corrosion by trapping alkaline solutions in contact with the glass. His comment No. 6 has an interesting bearing on why some paints may protect the base glass and others may accelerate the attack. Page 170 describes the special study made of Specimen J which suggested that it had not previously been coated with any form of oil paint or varnish.

On p. 172 it is noted that the use of hydrogen peroxide as a cleaning agent is not likely to be harmful, its action being partly to bleach organic deposits and partly to dislodge flakes by forming bubbles of oxygen around them. In a few cases "flashed" ruby glasses had been placed with the coloured side outwards and the corrosion then removed the colour; such pieces had to be plated with new ruby glass. In some cases double plating was used; this avoided the need for disfiguring lead lines and the technique of contour-moulding is described, attention being drawn to the need to eliminate moisture. Three of the glasses (A, B, and J) were analysed and were found to be low in soda (0.7-1.8%), high in potash (14.4-16.4%) and remarkably high in lime (15.6-23.9%). (Note by RGN: Professor Moore remarks that the sample with the highest lime content had much poorer durability than the other two, contrary to his expectation and to his bewilderment (top of p.174) but this view (in 1952) would not now be held and such a high-lime glass would be expected to show the heavy encrustation which had been encountered – see Reference No. 20 below but Professor Moore did speculate on this possibility – end of note by RGN.) Finally, there is a brief comment on the possible effects of bacterial or fungal action and the recommendation that sodium pentachlorophenate (Santobrite) should then be applied.

17. KORN, U-D. (1971) "Ursachen und Symptome des Zerfalls mittelalterlicher Glasgemälde" (Causes and symptoms of the deterioration of medieval stained glass), Deutsche Kunst u. Denkmalpflege 58-74.

This important, well-documented and profusely illustrated paper falls into three parts:- notes on the history of protection of windows; an account of the weathering of stained glass in relation to its composition and fabrication; and a discourse on the ways in which stained glass windows have deteriorated more rapidly in recent years.

The historical part (p. 58, col. 1) records the care which used to be bestowed on church windows (a wire grating at Lübeck in 1437, a copper screen at Xanten in 1547, etc.) and the permanent employment of professional glaziers (eg at Regensburg in 1450) which is only now being re-introduced anywhere. The windows of two cathedrals in Vienna were washed regularly during the middle ages. The section on fabrication and deterioration of glass (pp 58, col. 2 to p.67, col. 1) describes the varied nature of the weathering process and notes the very variable durability of ancient glass. The author comments that medieval furnaces were inefficient, the temperatures were low, the glasses needed a high alkali content to render them "soft" enough to melt, and their chemical durability consequently tended to be poor. The batch formulations were indefinite (1 part of sand to 2 parts of "plant ash") and thus variability in composition must be expected. Nevertheless, some 12th and 13th century glasses are remarkably durable but the great increase in usage of stained glass in the 14th century (connected with the increase in building activity) led to a deterioration in quality, but thinner and "harder" glasses became available in the 15th century (eg. compare the Luneberg glasses of 1390 and 1410).

The accounts of weathering are detailed but pitformation is attributed to "Fremdkörpern" in the glass (? is this true ? – RGN) and much emphasis is placed on Geilmann's analysis of the weathering crust at Ulm Cathedral (where he found a higher proportion of sulphates – syngenite and gypsum – than of carbonates in the crust). It is noted that the removal of the crust restores the transparency but naturally reduces the thickness of the glass and hence the intensity of the colour (regrets are expressed about the cleaning of the Obergaden windows in Cologne Cathedral) and solarisation is referred to in connection with the changes of tint. A recent source of accelerated deterioration of the glass is condensation on upper windows resulting from the installation of central heating in churches.

The formulation and application of paints is discussed and the statement is made (? which will surely be challenged? – RGN) that all medieval glass was painted on both sides but now the painting on the outside can be observed only occasionally because it has usually weathered away (see p. 64, col. 2, lines 11 to 20). Three kinds of weathering are identified:- painting intact but unpainted glass has weathered badly; the painting on the outside has weathered but the glass is relatively untouched; the painting and the glass have both weathered: all are described in detail and well-illustrated on pages 65-67.

The section (p. 67, col. 2 to page 72) on the increase in deterioration in recent years deserves special comment. Three cases are described in detail and there are some general statements about the "deterioration of the environment". First, however, (p. 67, col. 1) the author agrees that some windows had deteriorated long ago (1839 accounts of Nuremberg, Munich and Cologne) but damage in Nuremberg is linked with sulphurous acid released in the town during the sulphuration of hops (see below about doubts regarding SO_2 - RGN).

Case No. 1 is the Nuremberg Schlüsselfeder window of 1497, two panels of which were moved to a museum in 1831 and are in excellent condition. Figs. 19, 20 and 21 show another panel of the same window in 1900, 1943 and 1969 respectively; the condition is better in 1943 than in 1900 and much worse in 1969 and the deterioration is attributed to the "continuous effects of condensation". (NB the window was restored in 1909 and some repainting was done. ?Was it refired during the repainting? Could this have contributed to the further deterioration by 1969? - RGN.)

Case No. 2 (p. 68). In 1853 the Jesse Tree window in Legden was in an excellent state of preservation but a photograph in 1899 showed severe corrosion; in 1912 the design was indistinct; in 1948 an attempt was made to clean the window but the original transparency "could not be restored", see Fig. 22; between 1964 and 1969 the window again had to be restored because there was a thick weathering crust (only 15 years after "being cleaned") see Fig. 23. The window is now "a ruin" but few or any changes seem to have occurred between 1280 and 1853 compared with what has happened since then!; the reason is said to lie in a marked accumulation of CO_2 in the air (possibly also the central heating in the church) and of SO_2 (blamed for the formation of the crust on the outside). (Note by RGN: See below regarding SO_2 and CO_2; we apparently cannot disregard the possibility that the "treatment" in 1948 might in some way have contributed to the accelerated deterioration since that date. It would be satisfying to learn of a case where its state had been recorded at various dates but it had been left untouched throughout the period. - end of note by RGN)

Case No. 3. The Helmstedt Apostle window of ca. 1250, hidden during the Second World War, was replaced in 1947 but the wrong way around. In the previous 700 years the outside had suffered only moderately but in the last 20 years the inside (now outside) had been completely destroyed and the corrosion (again attributed to sulphate, but without evidence) had corroded the glass below the paint (Fig. 25). (Note by RGN: here, again, we do not have a straight comparison even though it is the base glass, and not the paint, which is being compared!)

From p. 70 onwards there is a discussion of environmental deterioration, stone, metal and glass being (apparently) lumped together; SO_2 and CO_2 are labelled the "aggressive agents" and it is stated that the increase in industry since the beginning of the century has caused increases in SO_2, CO_2 and fluorine compounds in the atmosphere. Domestic heating has also added SO_2 and CO_2 to the atmosphere and it is stated that 3.4 million tons of SO_2 are given off annually in West Germany. (Remarks by RGN: it comes as a surprise to glass technologists to be told that SO_2 is harmful to glass (des Hauptschädlings an den Fenstern) because it is used to treat hot glass bottles (soon after they are made) to improve their durability. Experimental work is needed to determine whether cold stained glass windows are adversely affected by SO_2 and it is not sufficient evidence to state that Gellman found sulphates in the weathering crust because the glass could have been attacked by carbonates and the carbonates then converted to sulphates without involving the glass. As regards the claim that SO_2 and CO_2 are increasing in the atmosphere, this is undoubtedly true in a technical sense but from a practical point of view it should be remembered that about two-thirds of the annual emission of sulphur into the atmosphere (about 220 million tons) comes from natural sources and only one-third from man-made sources (see Table III, p. 18 of Stanford Research Institute Report PR-6755 "Sources, abundance, and fate of gaseous atmospheric pollutants", February 1968). The author blames motor traffic for an increase in CO_2 (rather than the usual CO which worries environmentalists) but between 1860 and 1940 the CO_2 increased by 7.9%, and in 1962 by 15.2% (compared with 1860) and it seems that the increase is continuing at about 1.4% per year; in 1962 the CO_2 content was 315 parts per million. It thus seems that "central heating" may be more blameworthy or, if SO_2 and CO_2 are now more harmful, their effect is in some way other than by direct attack on the glass. Again, we really require properly-planned experimental evidence on the point - end of remarks by RGN.)

Finally, the author (in Note No. 30 on page 73) recommends protecting stained glass windows by applying protective glazing on the outside (to protect against outside weathering and condensation inside) and promises a report on the matter at the appropriate time.

18. LOWE, W. (1960) "The conservation of stained glass" Studies in Conservation, 5, 139-149.

This paper is concerned with the conservation of the stained glass collection at the Victoria and Albert Museum, and is thus not strictly relevant to the problems of conserving windows in situ; nevertheless there are several points of interest. There is a brief summary of the valuable pieces in the collection (p. 139) and of the types of deterioration present. His methods of cleaning include a "very weak solution of ammonia", followed very quickly by distilled water, but this must not be used on the painted surface of certain Renaissance panels (p. 140, col. 2). Pits are cleaned out with a lubricated dental burr and the holes are filled with tinted polyester resin or polybutylmethacrylate. In heavily-corroded areas the entire layer must be removed; hydrochloric or hydrofluoric acids were formerly employed but the work is now done by grinding. On p. 142 he contrasts the views of two authorities (Lewis F. Day and Noel Heaton) regarding the replacement, or not, of missing fragments.

He uses Araldite 103 for cementing pieces of cracked glass (p. 147, col. 2) but seems not to recommend it for use on an outside site. When painted detail has deteriorated he coats the surface with polybutylmethacrylate or polyvinylacetate.

19. McGRATH, R, FROST, A. C, and BECKETT, H. E. (1961) "Glass in Architecture and Decoration", 712 pages, Architectural Press, 1961.

This tome is of great interest for architects from the constructional point of view, and some reference is made to the weathering and the cleaning of glass. Page 426 gives an account of weathering (Note by RGN - but item No. 2, that the adsorbed water diffuses into the glass – could be misleading because the sodium ions diffuse out into the adsorbed water) and it points out that acids, except hydrofluoric acid (and certain of its allied compounds) do not attack glass. Alkaline paint strippers can harm glass. On p. 427 it is pointed out that a ground and polished surface is less resistant to attack by water and alkalies than is a fire-finished surface (because the fire-finishing causes some alkali to volatilise from the surface), and it is emphasised that glass in contact with "static water" (eg, if wetted when closely packed surface to surface) may be ruined in a few weeks; the surface becomes iridescent and the sheets may even become cemented together. Accumulations of dirt can hold alkaline solutions in contact with the surface (p. 428). Shrinkage of gelatine and glues, or even bill-poster's paste, can cause physical damage to the surface of glass.

Information about the cleaning of glass in buildings is given on pages 580-582, and the use of hydrofluoric acid is recommended on pages 427 and 580 (see quotations in item 4 of Reference No. 6 above). However, it is known that the paintings on some church windows have been damaged by the use of hydrofluoric acid, eg, at Gresford in North Wales (see p. 5 of Mostyn Lewis "Stained glass in North Wales", 1971) and at Southwell in Nottinghamshire. (Note by RGN: In this connection "Eutharkon No. 4", which is said to have been used on "some of the finest stained glass windows in a leading church in Wolverhampton with wonderful results" is believed to contain hydrofluoric acid; when using the material it is recommended to "protect hands by wearing rubber gloves, protect eyes with goggles, especially when drops or spray could otherwise enter the eye. Accidental splashes must be washed off skin and clothing immediately using plenty of clean water" – these quotations are from an Eukarthon No. 4 advertising leaflet - end of note by RGN.)

20. NEWTON, R. G. (1969) "Some further observations on the weathering crusts of ancient glass", Glass Tech. 10, 40-42.

This paper (which is concerned with excavated glass, rather than windows in situ) draws attention to remarkable differences in weathering of the excavated glass, presumably all made at the same site at Bagot's Park in about 1535. About 300 kg of glass was excavated and half showed a heavy weathering crust whereas the other half was quite uncrusted, yet all had been mixed in the soil and had apparently been subjected to the same "weathering". Chemical analyses showed only a small difference in composition which at the time (1969) was regarded as negligible, and the phenomenon was regarded as a mystery! (Note by RGN: Professor Douglas has recently (1972 - unpublished) done some work on this glass which suggests that the amount of lime in the crusted glass (about 13%) may have been sufficient to "pass the optimum for good durability" and thus lead to poor durability. We may thus be seeing one effect of glass composition.)

21. NEWTON, R. G. (1971) "The enigma of the layered crusts on some weathered glasses, a chronological account of the investigations". Archaeometry 13, 1-9.

This paper (also concerned with excavated glass rather than windows in situ) discusses all the work to date on the formation of layers in the crust, and concludes that they are not formed by an annual process. Pages 7-8 discuss a possible mechanism of the formation of the layers and it seems likely that a similar mechanism may be responsible for the weathering crust on medieval windows. The paper illustrates sections of "weathering plugs" which apparently correspond to the "weathering pits" found in windows. These grow down into the glass by some "activated" process but they are too long to correspond with a small impurity such as a sand grain and they form at right angles to the inhomogeneities to be found in flat glass (which lie parallel to the surface). Moreover, Fig. 1 shows that they can be "delayed" by an air bubble, rather than being "activated" by it as has been suggested by Frenzel and others.

22. NEWTON, R. G. (1972) "Stereoscan views of weathering layers on a piece of ancient glass". Glass Tech. June 1972 in the press.

This paper is of interest in showing what techniques may be of use to the Technical Committee in its researches into the nature of the "pierre du temps" or "Witterstein" on windows. It shows pictures of the weathering crust of excavated glass taken with the scanning electron microscope, and much detail is revealed. It also shows (Fig. 8) how the electron microprobe can be used to analyse the crust on a "micro-scale". Thus it might be possible in this way to obtain evidence as to whether the more recent layers (presumably the lowest ones) are more contaminated by sulphates from industry, than the earlier ones.

23. NEWTON, R. G. and WERNER, A. E. (1972) Definition of the term "devitrification" - unpublished correspondence.

Both contributors, and also Professor Douglas, are concerned by the loose way in which the term "devitrification" is sometimes used. Strictly, it means the formation of a crystalline phase from the amorphous glass and we believe that this can happen only when the glass is quite hot (above the liquidus temperature) - (RGN: Has anyone any evidence of devitrification in cold glass?)

Archaeologists have tended to use the term devitrification to mean the type of weathering which destroys the vitreous appearance of the glass. We three believe that the following definitions should be used:-

Devitrification occurs when crystals are precipitated from a glass during cooling. Devitrification takes place by a re-arrangement of the atoms already present in the glass and without the removal or addition of any other atoms to those originally present. The products formed when a glass devitrifies are crystalline and give characteristic X-ray diffraction patterns.

Corrosion, or weathering, of a glass is a phenomenon which occurs as a result of a physico-chemical reaction between the glass and its surroundings. As a result of the reaction, some of the original constituents of the glass are removed and its vitreous appearance is spoilt or destroyed. Usually the corroded surface fails to show the presence of any crystalline material, but if a crystalline material is present it is a result of the chemical reaction between the glass and its surroundings.

24. ORGAN, R. M. (1957). "The safe storage of unstable glass", Mus. J., 56, 265-272.

This paper is primarily concerned with the storage of glass articles in museums, when the potash content of the glass is so high that the surface "weeps" in damp atmospheres (for example, the Nuremberg jar dated 1630). The foreword by Miss Bimson (pp. 265-6) gives an interesting account of the requirements for a durable glass and the reason why high-potash glasses exhibit "sweating" on the surface. The solution to the problem is to keep the glass in a relative humidity of less than 42% and is thus feasible only in museums (because no coating is sufficiently impermeable to moisture to preveng the sweating from occurring at some time, and thus making matters worse!) but the paper is a warning regarding high-potash glasses.

25. RAW, F. (1955) "The long-continued action of water on window-glass: weathering of the medieval glass at Weoley Castle, Birmingham", J. Soc. Glass Tech. 39, 128T-133T.

This paper is primarily concenred with the formation of layers in the weathering crust of buried window glass but there are two points of special interest regarding the technical aspects of conservation. First, Fig. 1(a) shows a section of weathered glass and demonstrates how a very thin layer of black paint has prevented crust formation beneath it: however, the crust has developed in concentric layers at the two edges so as to "undermine" the paint. Second, Fig. 6 shows how weathering layers can cross lines of inhomogeneity: thus what had been visible inhomogeneities in the glass seem to be perpetuated as still-visible lines crossing the weathering layers and the progress of corrosion appears to have been undisturbed by the inhomogeneities.

(Note by RGN: In connection with the protection afforded by the black paint, there is no suggestion that the other surface has been affected by the changes on the "front" face, whereas many cases are known where the pattern of weathering pits on the outside of a stained glass window has (in some quite extraordinary manner) followed the pattern of painted lines on the inside of the window. This phenomenon is at present an entire mystery, but it should be remembered that Raw's samples had been buried in moist soil and the behaviour of windows in situ may be quite different. Nevertheless, similar sections should be cut through fragments of windows which show this phenomenon - end of note by RGN.)

26. UNWIN, Max. (1951) "A treatment for the preservation of glass", Mus. J., 51, 10.

He points out that the iridescence and opacity of ancient glass is due to a laminated crust and the transparency can be restored by impregnating the crust with a medium having the same refractive index. He used polyvinylacetate dissolved in toluene (25% w/v) (there is an error in his quoted refractive index for Roman glass: it should be about 1.5, not 1.15 - RGN) and claims that it does not discolour appreciably with age and the treated glass is almost impossible to distinguish (by eye) from undecayed glass. The treatment is described (it takes half an hour) and the object is strengthened at the same time. Many articles have been treated and he implies that the polyvinyl chloride can be removed with toluene.

Note by RGN: This first selection of abstracts will be followed by supplementary documents because less than half of the important literature has yet been covered.