

**School of Design and Art  
Department of Design**

**Aesthetic, Creative and Innovative uses for Photosensitive Glass in  
Art-glass Production: Case Studies in Studio Practice**

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**This thesis is presented for the Degree of Doctor of Philosophy  
of  
Curtin University of Technology**

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**Declaration**

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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Date: .....

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## TITLE OF THESIS

Aesthetic, Creative and Innovative uses for Photosensitive Glass in Art-glass Production: Case Studies in Studio Practice.

## ABSTRACT

This research is situated in a space between the broad fields of art-glass design, art, science and the technology of alternative photographic printing processes. It is an experimental project with a core research question. *‘Can photosensitive glass be made more accessible to artists working in art-glass, design or art practice’?*

The focus of this research is located in the almost forgotten niche of *‘photosensitive’* glass. *‘Photo-sensitive and photo-chromic glasses contain ultraviolet light-sensitive metals, gold, silver or copper. The selective development of color can be controlled by placing a mask or photographic film in contact with the glass. When exposed to ultraviolet radiation, then heated, the glass changes from clear to opal, reproducing the pattern on the glass. The image developed is permanent and will not fade as would a similar image in photo-chromic glass.’* (Kohler 1998, 23-24). *Glass: An Artist’s Medium*. Section 2. Properties of Glass. Iola, WI54990-001. USA: Krause Publications.

Through systematic experimentation, the methods indicating how photosensitive glass can be incorporated into selected traditional glass-making techniques have been identified. Traditional glass making techniques include:

- Pulling of molten glass from a glass furnace to make stringers, canes, rods, murrine and/or mosaics a hot glass technique.
- Crushing and recycling, making chunk de verre and pate de verre, a warm glass technique.
- Bead-making, button-making and core-forming, all hot glass techniques.

- Kiln work in the form of kiln casting/slumping and simple open-face Pate de Verre, a warm glass technique.
- The casting of molten glass from the glass furnace into sand for sand-casting and the forcing of hot molten glass into moulds are hot glass techniques.
- Free-blowing and mould blowing, hot glass techniques.
- Acid etching and acid embossing, particularly hazardous cold glass techniques are only discussed not attempted.

These selected techniques are presented as case studies that have been analysed and the experiments documented to identify methods and processes that demonstrate the potential of photosensitive glass as an art medium. The details of successful experimentation are fully documented according to a laboratory processes, formulae and colour analysis. This extensive research material will hopefully enable designers and glass artists to extend their creative practices and when using the outcomes to develop hybrid and innovative processes in a wide range of contemporary studio based and commercial applications. The research outcomes of this enquiry into the use of photosensitive glass in creative glass processes represent an extensive and original contribution to knowledge that I hope will be shared by studio artists and commercial glass professionals in art and design.

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It is with pleasure to take this opportunity to thank David Hay of Hyaline Hot Glass Studio, Edith Cowan University for being so generous in allowing me to act as a participant observer/part-time assistant at the studio from March 2003 to 2008. I wish to thank my art-glass making colleagues and the many visiting glass artists to the studio for their interest, encouragement, discussions and advice. In

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Heather May

Perth, Western Australia.

9th December 2010.

## **DEDICATION**

This research is for my grandchildren Conrad, Lauren, Rowen, Melanie, Fergus, Rhiannon, Harriet and Ashton.

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# CHAPTER ONE

## 1.0.0. INTRODUCTION TO THE FOCUS OF THE RESEARCH

The focus of this research is located in the almost forgotten niche of ‘*photosensitive*’ glass.

*“Photo-sensitive and photo-chromic glasses contain ultraviolet light sensitive metals, gold, silver or copper. The selective development of color can be controlled by placing a mask or photographic film in contact with the glass. When exposed to ultraviolet radiation, then heated, the glass changes from clear to opal, reproducing the pattern on the glass. The image developed is permanent and will not fade as would a similar image in photo chromic glass.” (Kohler 1998, 24).*

Through systematic experimentation, how photosensitive glass might be incorporated into some selected traditional glass-making techniques is identified. These experimental results will enable designers/glass artists to extend their creative practices to develop hybrid and innovative working processes. The outcome of this research answers the core question and is an original contribution to the discipline’s knowledge of how to use photosensitive glass in creative glass processes. The selected traditional glass making techniques for this experimental research are presented as case studies that have been analysed, and the experiments documented to identify methods and processes that demonstrate the potential of photosensitive glass as an art medium. In blurring the boundaries between art, design, science and technology, a new space became an area of investigation. This space has now become the focus of new artistic and theoretical possibilities. New innovative glass-making processes were developed and created when experimenting in this newly created space with late 19<sup>th</sup> century alternative photographic printing processes, selected traditional glass-making techniques and photosensitive glass. This combination of technologies required innovative and entrepreneurial application, and because this research is a

materials-based, practice-led experimental research, grounded in art and design, new ideas about the value of material research were developed. The experimental form of the scientific method<sup>2</sup> was chosen in order to achieve the objectives of this work. Selected traditional glass-making techniques considered to be suitable for the incorporation of photosensitive glass, were at first subjected to systematic experimentation. These experiments were labeled ‘scoping’ experiments and will be discussed in Chapter Four. When a scoping experimental result indicated a positive outcome, further sequential experiments were made. The identification of the potential of these experiments was assessed by analysis to see whether it could lead to additional applications in other creative fields.

### **1.1.0. Background to the research**

This process and materials-based research explores the potential for a symbiotic relationship between art, design, industry and technology. Petrie (2007, 1) observed that there was a growing trend in the ceramic and glass design sector for developing new research methods that blended the haptic and tacit skills of the designer-maker with approaches from other fields such as; science, engineering, industry and computing, often establishing the necessity of establishing multi-layered collaborative research strategies. Figure 1: The Broad Field of Research to the Narrow Focus of the Research Problem illustrates the background to my research (Perry 1998, 1). The four key areas of art-glass, glass technology, collaborative work and alternative photographic techniques were investigated and brought together to achieve the aims and objectives of this research. Figure 2: Situating the research development area in relation to the literature illustrates where my research is located and Figure 3 illustrates the selected traditional art-glass techniques that I estimated to be suitable for experimentation in trying to incorporate photosensitive glass (Love 2006). Although this research included

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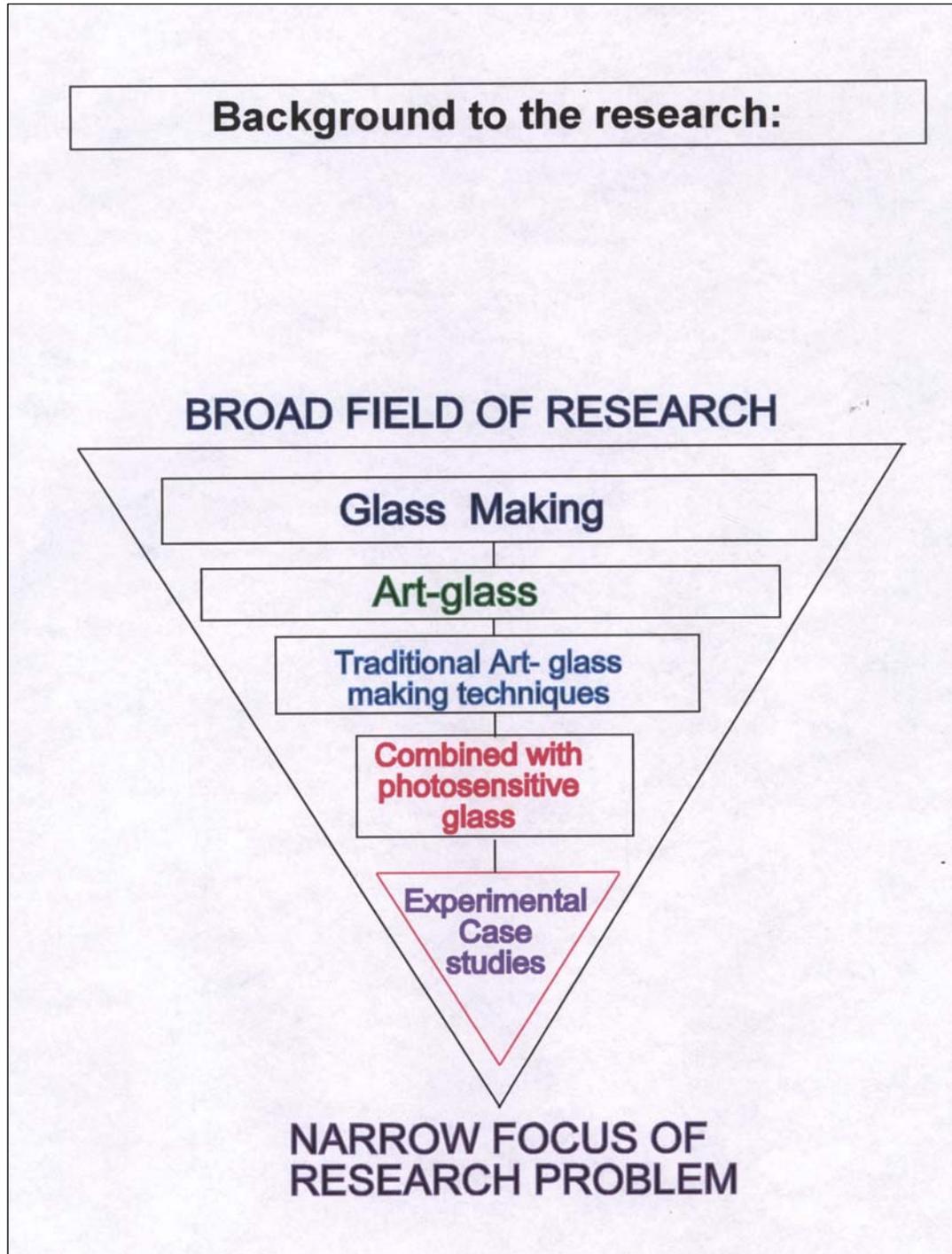
<sup>2</sup> There are two forms of the Scientific Method:

1. Experimental – collecting numerical data, graphs and tables (used by the physical scientists) to describe physical behaviour.
2. Descriptive – gathering information through visual observations and interviewing (used by biologists and anthropologists) (Allison, O’Sullivan and Owen 1996, 7-29).

rigorous experimentation, the main purpose was to demonstrate, document, reflect on and evaluate the importance of developing innovative hybrid creative glass-making techniques through the incorporation of photosensitive glass. Petrie (2007, 1) advocates using a Venn style diagrammatic model for developing a sector or subject area. He believes that by using such a model, the outcomes have the potential to be original, innovative and creative leading to further potential development. Figure 2 is a Venn diagram that situates the research development area in relation to the literature, and shows that the overlapping areas between the sectors of the fields of art-glass, design, science and photography, which has led to the creation of a focal space for experimental research. In this potential developmental space between the sectors, the gap that exists in the technology of glass design, glass-making and photography has been partially filled through this research. Each circle represents a field or subject area. All the fields have specific approaches, techniques, histories and methodologies. The potential research development focus was always the interface between the fields. This concept was based on Petrie's model for sector development. In my research, this interface between the fields was a space where I could focus on a new specialist area. Petrie (2007, 2) argues that because the field of art-glass practice is in certain aspects very self-referential and insular as is the field of ceramics, it often leads to a development limitation. By using the Venn model as a strategy, this strategy could lead to refreshing the field.

*“The research leading to the development of photosensitive glasses was initiated by a discovery by R.H.Dalton while working at Corning glass works in New York in 1937”* (Croucher 1991,3). Dalton's discovery was taken up with great enthusiasm by a co-worker at Corning, a young scientist who was to become internationally renowned for a startling range of glass inventions, Dr S. Donald Stookey, glass chemist, industrial research and inventor. Stookey discovered that he could produce photographs in photosensitive glass by exposing the glass to ultraviolet light radiation through conventional photographic negatives and then heating the exposed glass to develop the latent image (Woodward 2000).

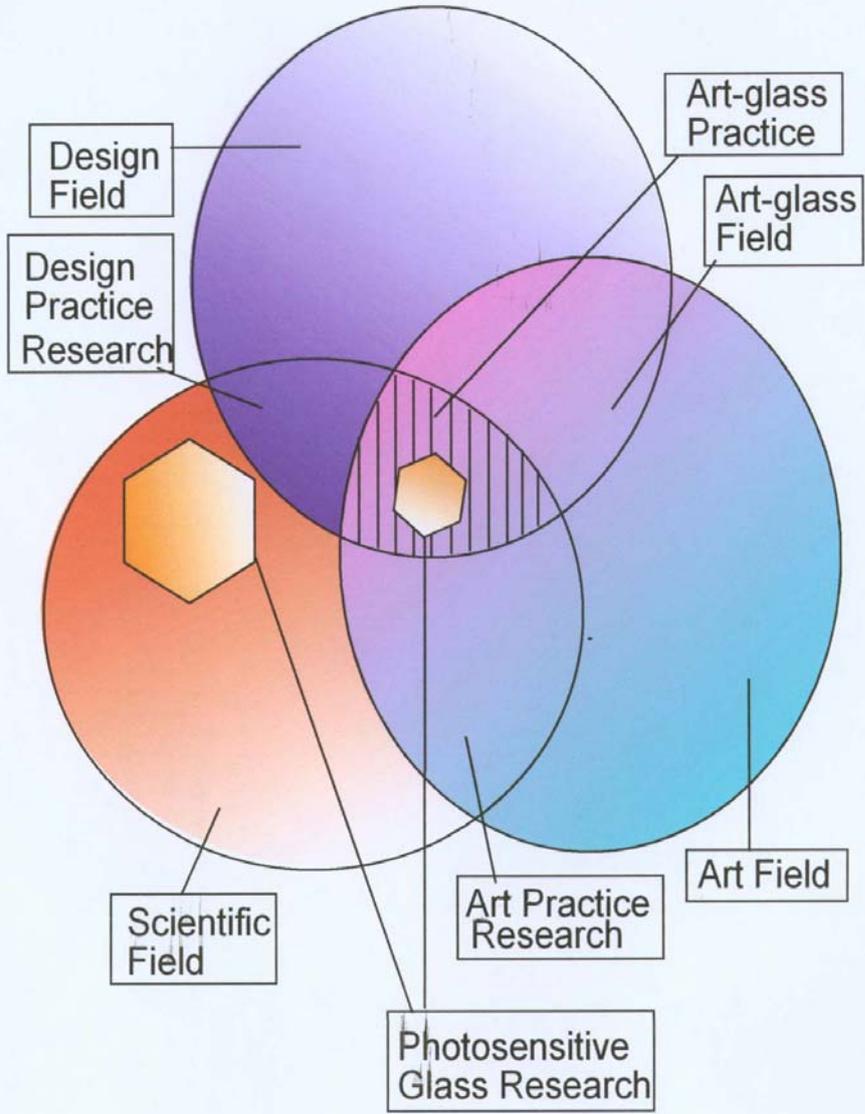
**Figure 1:** Broad Field of Research to Narrow Focus of Research Problem (Perry, 1998, 1).



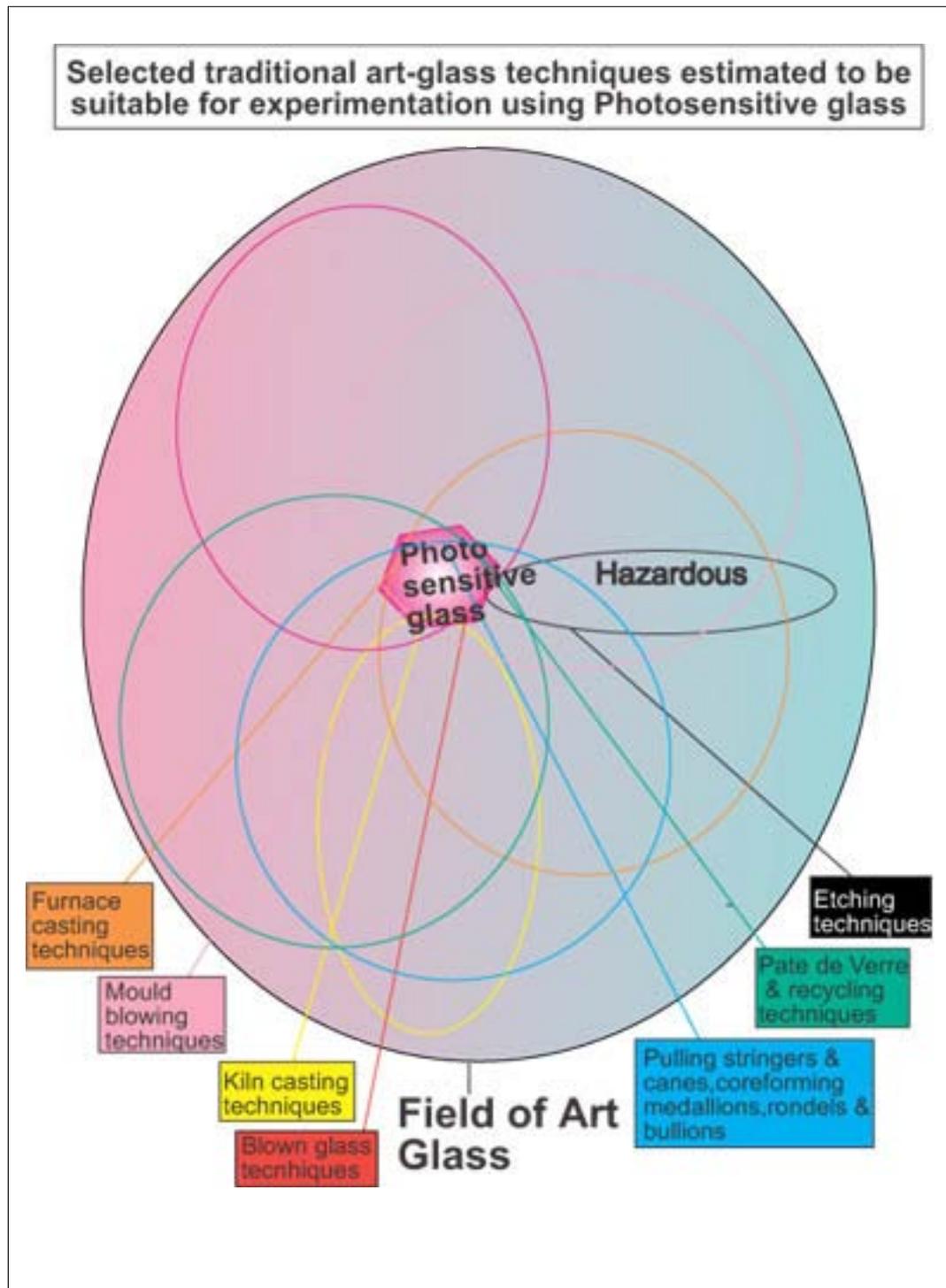
**Figure 2:** Situating the Research Development Area in Relation to the Literature (Love 2006).

## Situating the Research Problem Area in Relation to the Literature.

Practice, Research, Parent Disciplines & sub-disciplines.



**Figure 3:** Selected traditional art-glass techniques estimated to be suitable for experimentation using photosensitive glass (Love 2006).



## **1.2.0. Research problem and hypothesis**

### **Research question**

*Can photosensitive glass be made more accessible to artists working in art-glass, design or art practice?*

The question of how to incorporate photosensitive glass into some of the traditional art-glass making techniques needed to be addressed. To begin with, several traditional art-glass techniques were selected and by using the experimental form of the scientific method, the selected traditional art-glass techniques were subjected to several random methods of incorporating photosensitive glass into the making process. Each selected technique was represented as a case study. The ‘*scoping*’ experimentation was innovative and random in application. When the potential for each scoping experiment was realised, further sequential experimentation was carried out to discover whether the innovative scoping experiments could be repeated. Occasionally, three or more variations of each scoping experiment were attempted until a suitable viable experiment was able to be designed. Sometimes the scoping experiments did not work at all. The scoping experiments can be viewed in Chapter Five and the final experimental outcomes can be viewed in Chapter Six. This was due mainly to the high heating processes required by the particular traditional technique. It was then that an hypothesis was formed based on the outcome of ultraviolet light exposure times and the heat development temperatures of the scoping results of each case study.

### **Hypothesis**

It is postulated that the relationship between exposure times of photosensitive glass of a specific thickness under controlled ultraviolet light conditions and development temperatures under timed digital control in an electric kiln can be

used to develop a range of colours within the glass body thereby facilitating the placement of an image within the glass body.

Photosensitive glass is only obtainable in Australia in rod-form from Gaffer Glass, Auckland, New Zealand. A preliminary '*flaming*' or heating in a glory-hole is necessary for Photosensitive glass to react to ultraviolet light and it also requires a pre-heating temperature stage of 565 degrees Celsius in a hot box before picking it up on a punty or a blowing iron for the '*flaming*' stage or it will not stick to the punty. It is a very stiff glass to work with and sometimes red or pink coloured streaks or '*threads*' appear in the glass-body during the time it is exposed within the heat of the glory-hole, see Figure 8. The appearance of these streaks, or '*threads*' in the body of the photosensitive glass was an indication to me that the photosensitive glass was ready to be blown or worked. This observation came about through experimental trials when using the glass in a '*raw*' state and comparing the results when using a '*flamed*' glass. There was no colour development when the '*raw*' glass was used in the scoping experiments. Previously '*flamed*' photosensitive glass must be removed from the annealing kiln in indirect light or under incandescent/halogen/LED light. Direct sunlight and mercury vapour fluorescent light should be avoided. It must be stored away from all light sources and placed in a black photographic plastic envelope until ready for ultraviolet light exposure. Ultraviolet light equipment is necessary to develop a latent image. A rotating turn table under the ultra violet light exposure apparatus is recommended for uniform exposure of the latent image.

Working with ultraviolet light is hazardous and health and safety precautions are necessary see 3.3.2a. HEALTH AND SAFETY ISSUES, page 69. Experimental tests for optimum colour achievement under ultraviolet light exposure are essential for successful results. After exposure to ultraviolet light the photosensitive glass object must be returned to the light-excluding photographic envelope before being taken to an electric kiln for heat development. Heat development of the ultraviolet light exposed latent image can be achieved in an

electric glass kiln controlled by a computerized digital controlled timer to achieve maximum expected results. Heat development in a gas-fired kiln has not yet been attempted as I consider controlling temperatures using gas too variable and difficult.

**Figure 8:** ‘Threads’ or streaks of red within the photosensitive glass body as seen at the glory hole.



### 1.3.0 Justification for this research

My justification for this research comes from the International Glass Art Society Conference held in Seattle, Washington State, USA, in December 2001. A question was posted on the Conference's Posting Board:

"Conference Call". Question 35: "*Could you tell us about the photosensitive Gold Ruby (G-221)?*"

Answer: "*Well, we're actually particularly proud of introducing the photosensitive Gold Ruby (G-221). And we are kind of surprised that nobody has grabbed the ball and run with it. It is one of the first really new things that's come along in glassblowing in the last 400 years. And, amazingly enough, it's been invented by Americans, and we've really done nothing much but take photosensitive Gold Ruby. And we've really kind of surprised that nobody has the knowledge that's been produced in America and made it available to the studio glass scene*".

During the 1950's and 1960's Corning Glass made photosensitive glass available as a novelty glass but it was not exploited further. Woodward (2000, 2) in her editorial on S. Donald Stookey, writes that he had commented that the sub-section of novel photosensitive glass had the potential yet to be proved as an art medium despite the fact that research involving the many application of photosensitive glass in the scientific field continues to flourish. My research was built on his initial inventions, experimentation and prediction that photosensitive glass has the potential to be used as an art medium. "*Given the explosion of so-called studio glass making around the world over the last 25 years, one would have expected at least some experimentation in this area, but to the authors knowledge there has been none at all although the early literature frequently mentions the good possibilities for using photosensitive glasses in the decorative ware, there seems to be no recent exploitation of its properties*"(Croucher 1991,28). Gaffer Glass of Auckland, New Zealand has re-worked Stookey's original recipes for photosensitive glass, making it compatible with the typical soda lime glasses used

by the studio glass blower<sup>3</sup>. John Croucher and John Leggott are co-owners of Gaffer Glass. “A *fundamental decision was made to research gold based glasses, primarily because of the greater colour possibilities compared to other noble metals*” (Croucher 1991, 28).

A ‘*free of charge*’ Symposium was held by John Leggott at the Chihuly Boat House Studio on the 12-13 June 2003 during the International Glass-Art Society Conference in Seattle with the hope of promoting photosensitive glass to practicing glass artists. The main concern of the artists and designers who attended this symposium was that it was too time-consuming to do research on the properties of photosensitive glass and then figure how to apply the research to their current work. This view was confirmed to me in a personal communication with a young visiting glass blower from the USA<sup>4</sup> at Hyaline Hot Glass Studio. Stout’s opinion is supported by Paul (1990, 333) (taken from the section of Photosensitive glass in the Dictionary of Scientific and Technical Terms 2003) who argues that some of the reasons for not developing photosensitive glass since its patent were that it is labour intensive to produce and work with as well as being very expensive.

My justification for designing methods for incorporating photosensitive glass in selected traditional glass-making techniques was based on that concern. There is therefore potential to research the medium and make the results available to the glass community. Innovative use of photosensitive glass continues to be and has been researched, documented and published in the scientific literature. Polychromic (full colour) photosensitive glass, as opposed to the current Gold Ruby (G-221) glass, is not yet available for the glass artist in rod-form for artwork. This paper describes new polychromic (full-colour) photosensitive

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<sup>3</sup> Soda-Lime Glass is a glass of high soda content that can be dissolved in water as a syrupy fluid. Most manufactured glass is a soda-lime composition used to make bottles, tableware, lamp bulbs and window and plate glass (“Glass” Microsoft Encarta Online Encyclopaedia 2008).

<sup>4</sup> Paul Stout from Tucson Arizona, USA was a visiting glassblower/assistant to David Hay and Holly Grace at Hyaline Hot Glass Studio, Edith Cowan University, Perth, Western Australia (2005).

glasses in which the full-colour spectrum is developed by photochemical precipitation of sub colloidal silver too small to scatter light...Colors may be developed in either clear or opal areas; they can be restricted to the surface of the glass or generated to a great depth. *“While studying certain silver-containing photosensitive sodium fluoride opal glasses, an unexpected and complete colour spectrum was observed when a secondary ultraviolet exposure/heat treatment operation was superimposed upon the normal cycle required to produce the photo-opal. This observation led directly to the investigation reported in this paper”* (Stookey, Beall and Pierson 1978 49, (10): 5114-5123). Based on this scientific research I believe there is a potential for further research work in this art glass area. In particular, this materials research has a contextual place in creative design practice. Materials research can contribute to new innovative industries in the long-term (Fazackerley 2005). This research has therefore concentrated on examining and documenting photosensitive glass as a case study of materials research for art practice.

This research extends my design honours project of 2004 ‘Colour Development by Systematic Experimentation: Placing a Photographic Image within the Glass Body’. The emphasis then was on placing a photographic image within the glass body using photosensitive glass. The processes involved to develop images in Gaffer#080 ruby will not be covered in this thesis. Subsequent literature searches have shown that there is potential for further uses of photosensitive glass in art-glass making. This will be covered in the literature review documented in Chapter Two.

#### **1.4.0. Scope of this research**

Selected traditional glass making techniques for this experimental research are presented as case studies. The experiments for each case study are documented and analysed to identify methods and processes that demonstrate the potential of

photosensitive glass as an art medium. This research demonstrates a changed dynamic, where experimentation can take the lead but nevertheless will be a catalyst for high quality aesthetic production.

### **1.5.0. Aim of this research**

To investigate how selected traditional glass making techniques, photosensitive glass technology of the 1950s, and the adaptation of old alternative photographic printing techniques of the late 19<sup>th</sup> century, could be brought together to provide new opportunities for designers and glass artists.

### **1.6.0. Theoretical framework and methodology**

Simon Blackburn (2008,3) editor, defines ‘methodology’ as being a body of practices, procedures, and rules by those who work in a discipline or engage in an inquiry - a set of working methods as defined in the Oxford Dictionary of Philosophy (2008, 3). The theoretical framework used in this research was grounded in practice and was based on the experimental form of the scientific method (Allison, O’Sullivan and Owen 1996, 7-29).

In the early years of the 19<sup>th</sup> century, the development of photography led to the phenomenon of solarisation. The phenomena of solarisation and photosensitisation involve the processes of oxidation and reduction. There are not many differences between the two phenomena as they are complementary, because one cannot take place without the other. Under the influence of ultraviolet light, oxidation and reduction processes are nothing but the losing and gaining of electrons, affected by the passage of radiations through the glass. Interest faded fast when more sensitive photographic plates were invented and the research leading to the development of photosensitive glasses was initiated. Solarisation can be made reversible and differs from photosensitive glass which is non-reversible – unless

the glass is completely remelted. Secondly, because heat treatment is required to make the latent image, that is produced in the glass by radiation, visible. In solarisation, the colour is produced by the transition of electrons of some ions to other orbits without heat being involved (Croucher 1991, 6).

Alternative photographic printing technologies of the late 19<sup>th</sup> Century such as Gum Dichromate printing and Cyanotype printing were adapted together with inkjet printer technology to create digital negatives, and this adaptation was used on a material other than photographic paper. Burkholder (1999) writes that a digital negative is like any other negative except that it is made using the computer instead of using traditional wet chemistry in the photographic darkroom. This combination of digital technology with traditional fine art photographic printing was explored by me in 2004<sup>5</sup>. Nored (2008) suggests that because inkjet printer technology has improved significantly over the past few years, this technology is now up to the task of creating large format negatives for contact printing. He suggests that instead of applying adjustment curves to the *positive* form of an image as Burkholder (1999) advises and getting weird results, adjustment curves should be applied to the *negative* of an image. New materials are now available that allow the printing of maximum resolution images without ink-puddling therefore spectral density negatives are no longer required. By working directly with the negative of an image, this allows one to see and appreciate how changes to the curve affect the print (Nored 2008). Using this adaptive technological information to produce a range of colours for further innovative artistic development in the selected traditional glass making techniques incorporating photosensitive glass enabled me to carry out further experimental work. The documentation of the art-glass methods, experiments and processes, that demonstrated the potential of photosensitive glass as an art medium, were then analysed to confirm how it is an important aspect of art practice today.

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<sup>5</sup> Photosensitive Glass Colour Development by Systematic Experimentation: Placing a Photographic Image within the Glass Body by Heather May, 2004.B.A (.Design) (Honours), Curtin University of Technology, Bentley, Perth, Western Australia.

In addition, I used the case study experiments, participant observation in the hot glass studio plus the results of collaborative associations as methods for collecting data for this research. Because my interests as a researcher far outweigh my ability as a glass-artist I developed a number of collaborative associations with other practicing glass artists. These collaborative associations are closely related to the objectives of this research. The definition of ‘*collaborate*’ is to work jointly (with) especially at literary or artistic production<sup>6</sup>. It was anticipated that this research would provide an account of the relationship between technical, artistic and intellectual knowledge within communicative [collaborative] practice in art glass production and therefore provide recognition of the potential for a changed relationship between technique and aesthetics in art glass, adding to the body of knowledge about art glass and its production. (Friedman 2000) argues that contemporary design practice is now characterized by collaborative interdisciplinary and strategic approaches demanding the designer’s knowledge-base to extend beyond tradition design related activities. Collaboration amongst glass artists is well documented (Klein 2001) and there is a shift of thinking by the design profession towards interdisciplinary collaboration.

Many artists have discussed the relevance of interdisciplinary communication between artists. For example, Robyn Stewart, (2001) argues that the joining of seemingly dissimilar phenomena often triggers innovative thinking and that to develop new or alternative pathways to empower praxis. She states that there are potentially as many different approaches to research as there are practitioners in the field. Danner and Danner (2005, 1) explain that interdisciplinary communication is vital to artistic cross-pollination in that it that allows the work to remain interesting and often results in brilliant work, sometimes much better than each creator could produce on their own. One of the now recognized means of communication or collaboration is through working in a ‘*Creative Cluster*’<sup>7</sup>.

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<sup>6</sup> The Pocket Oxford Dictionary. 6<sup>th</sup> edition 1978. Oxford University Press.

<sup>7</sup> Florida Richard 2003-2005. Florida Creative Cluster <http://www.onenortheast.co.uk>.

Materials research has a contextual place in this type of creative design practice. It has the potential to contribute to new innovative industries, lead to products for new audiences as well as current audiences, and inspire new work with potentially new economic outcomes. Existing collaborative models in design, art and architecture include the work of Jim Roddis of Sheffield Hallam University, who pioneered a technique so that houses could be designed and built with glass walls tougher than concrete<sup>8</sup> and the work of eight wood designers who have studio space in an old pattern workshop situated in the old railway workshops in Midland, Perth, Western Australia. *“FORM’S cluster model is intended to formulate and refine a strategy for assisting artists and designers to make the leap from an emerging business to an established and commercially stable enterprise. FORM’S focus on carving out a pathway between creativity and sustainable commercial success has attracted considerable support from both the State Government and the private sector”*<sup>9</sup>.

Examples of successful collaborations among glass artists and designers who are internationally recognized include the following:

- United Kingdom: Anna Maria Dickinson, Neil Wilkins and Mehmet Kazu. [Blown, cut and electroformed]. The outcome of this triple collaboration is a very different surface appearance on the blown vessels.
- Czechoslovakia: Stanislaus Libensky and Jaroslava Brychtova [Cast glass] first collaborated on a glass-related project in 1956 and were very influential in Czechoslovakia (Klein 2001:12).
- Italy, USA and Australia: Italian glassmaker Lino Tagliapietra [Blowing and kiln forming] introduced the Italian way of glass making at Pilchuck

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<sup>8</sup> Professor Roddis is head of the University’s Cultural Research Institute and holds two patents for glass that could be used for structural walls without harming the environment. Designing the right material was only part of the problem. (The Times Higher April 2005:12.).

<sup>9</sup> Low C 2005. *Western Australia’s Creative Clusters*. FORM magazine.3<sup>rd</sup> edition:13.

in 1979. In 1988 he began his collaboration with Dale Chihuly, working on a series called 'Venetians'. This was an International collaboration involving artists from Italy, the United States, and Australia. The Italian technique has become one of the principal techniques used by contemporary glass-makers and as a result has also led to the development of new kinds of coloured glass at Bullseye in Portland, Oregon, allowing for a greater degree of colour compatibility and enabling blowing and kiln-forming techniques to be combined for the first time.

- USA: Joey Kirkpatrick and Flora Mace [Painting on glass and glass sculpture] developed a technique of drawing on glass by fusing coloured glass threads onto the surface.
  
- Australia: Kirstie Rea and Scott Chaseling [kiln forming & blowing without the use of a furnace] demonstrated and shared, in their teaching, the outcomes of combining kiln-formed and blown-glass, a technique that has become renowned as the 'Aussie Roll-up'. The outcome from inventing this technique meant that the hot-glass furnace could be eliminated; greatly reducing running costs (Hinchcliffe, Meredith. 2001). Klaus Moje [fused glass mosaics and blowing] has, since 1993, collaborated with American glass blower Dante Marioni.
  
- Western Australia: David Hay [glass blower and glass artist] of Hyaline Hot Glass Studio, Edith Cowan University, Perth, collaborates with the following glass artists and glass designers - Tony Hanning, [sandblaster & engraver] South Australia; and in Perth the following makers - Alasdair, Rich, and Kevin Gordon [master glassengravers and glass designers], Gordon Studio; Jasper Dowding [glass blower and glass artist], Rodney Coleman, [glass designer], Trudy Hardman, [furnace caster and beadmaker]. Jasper Dowding also collaborates with Bevan Thompson [Indigenous artist and ceramicist], Perth, Western Australia.

For my research, collaborations have established with glass artists/designers at Hyaline Hot Glass Studio in the six/seven traditional working areas see Figure 9(a) and Figure 9(b). Pilot or scoping experiments using photosensitive glass in innovative ways have been documented in written form and in photographic form and incorporated in my research plan. I argue that working and communicating with other artists offers challenges and rewards, very different from those encountered by working in isolation. Communication between the arts and other disciplines or between fields is growing in popularity often leading to new audiences. Fazackerley of *The Times Higher Education Supplement* (April 2005:12) reported that arts funding organizations are now actively encouraging inter-disciplinary communication especially those involving new technologies. Anecdotal information states that many artists enjoy working with other people regardless of their discipline. Relationships between art and technology are being established and hybrid forms of practice that bridge the gap between art and technology are becoming more evident. These innovative practices are beginning to demonstrate the imaginative application of new forms of art practice. These new creative outcomes are pushing at the boundaries of art and design disciplines. Such creative practices in art and design demonstrate a range of new novel applications for computer-aided design. Computer aided design software is now considered as a medium for active experimentation however a few critics have suggested that human creativity and experience have been threatened (Thirkell and Walters 2007, 240). Sometimes conflict can result in works that transcend the imagination of any single creative mind. The process of resolving disputes and being forced to think in new mutually compatible directions is part of the art practice journey. The resolution of disputes often inspires the involved artists as much as the finished work. When artists work across media independently the final result may be similar but the process is different. The challenge is for the artist to have a balanced expertise in each medium being used. Learning new artistic languages or translating between artistic media is difficult and time consuming therefore communication is vital.

### **Participant observation**

To achieve my objective of selecting suitable traditional art-glass making techniques suitable for photosensitive glass incorporation I established regular communication with other glass artists and I worked as one of the assistants to David Hay at the Hyaline Hot Glass Studio. My focus was to record in written form, to record my observations by using a digital camera and on video camcorder tape. My written and video-graphic observations on the various techniques used by the many designers/glass artists using the hot glass studio played an important role in establishing the assumption that photosensitive glass could be incorporated into some of these traditional techniques. Arguments in favour of participant observation include reliance on first-hand information, high face validity of data, and reliance on relatively simple and inexpensive methods (Zelditch 1962). This observational method enabled the collection of valuable data for use within my research-led practice.

**Figure 9(a): 1.6.0. Collaborative Work**

*Photosensitive glass bead-making in collaboration with Mrs. Trudy Hardman 2007.*



*1. Trudy at bead-making bench.*



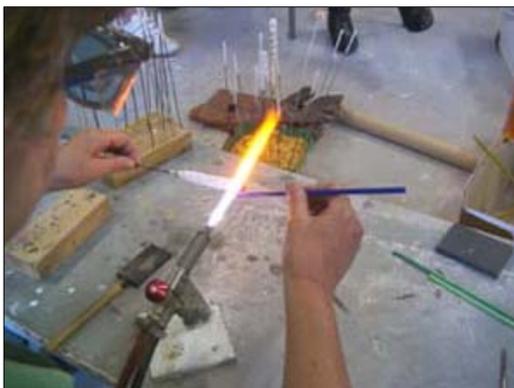
*2. Bead-making equipment, oxygen & gas.*



*3. Trudy dipping mandrels in resist.*



*4. Applying torch flame to bead.*



*5. Bead being torched & turned on mandrel.*



*6. Photosensitive glass chips covered under right hand.*

**Figure 9(b)** 1.6.0: Participant observation at Hyaline Hot Glass Studio.



### **1.7.0. Objectives of this research**

The objectives of this research are linked to the theoretical framework and the methodology.

**Objective one:** To survey of the history of photosensitive glass and its standard applications. This is covered in Chapter Two. A contextual literature review was undertaken. This review included photosensitive glass applications in the disciplines of science and art. Books, journals, articles and reports as well as online sources were included. Sources identified for detailed study are listed in the references section.

**Objective two:** To undertake a thorough on going art-glass literature review of art magazines, art books, art journals, conference proceedings and similar online sources. Discussions and interviews with local and interstate glass makers/artists and international glass artists through membership of bulletin boards and email correspondence was undertaken. Preliminary experiments to create scoping experiments using photosensitive glass were made.

**Objective three:** Involved the identification of the range of traditional art glass-making techniques that would benefit from the incorporation of the photosensitive glass making processes. This identification was made possible by working as a participant observer and assistant to glass maker/artist David Hay at Hyaline Hot-glass Studio on a regular basis (once a week from March 2003 – to August 2007 and at irregular intervals during 2008). The identification of several potential art-glass techniques suitable for the incorporation of photosensitive extended the literature review of glass making and included participation in glass making workshops and demonstrations involving the various techniques and processes as well as collaboration with other glass artists. Opportunities for attending glass conferences and regular visits to art-glass exhibitions and art galleries were followed up as opportunities arose. This objective is covered in Chapter Three under theory, materials and research methods.

**Objective four:** Experimentation was its base line; this is described in detail in the plan of work. The evaluation uses the data collected through participant observation and case studies, which are described in detail and is covered in Chapter Four.

**Objective five:** To demonstrate, document, reflect on and evaluate the importance of the innovative use of photosensitive glass in creative art-glass production and add some value to out existing knowledge in this area therefore answering the question *Can photosensitive glass be made more accessible to artists working in art-glass, design or art practice?* This objective is covered in Chapters Five and Six.

### **1.8.0. Developing apparatus, materials, method and processes**

A greater understanding of the materials and processes in design/art-glass was needed as was the ability to understand and control the materials and processes. This ability is often described as tacit knowledge. This tacit knowledge is understood and is often not openly expressed in art practice. The '*hands-on*' or haptic and tacit skills of the designer/art-glass maker should not be underestimated. An intimate understanding of the control of the materials with which they have been working over many years of practice would have developed...designer/glass-makers are usually able to identify problems, issues and/or new opportunities that might form the focus for a new developmental direction in their practice from their long experience with working with the material. This understanding is often aided by collaborations within the fields of design, art and science. This blending of approaches could lead to new creative advances in the field of art-glass practice. Petrie (2007, 3) describes the blending of the fields as a 'Boolean' approach and cites the work of Yrjo Engestrom on 'Activity Theory and Expansive Design' as providing a detailed theoretical perspective and visual model for this type of development. The newly created development area in my research gives advantage to the design and art sector over the other sectors. Petrie (2007, 3) argues that this need not be a problem, providing a strategy can be maintained for knowledge, experience or approaches from one sector to the others such as in the case of buying collaboration. Payment for this purchase may be given in kind. This is a trend that is emerging in the research community (Petrie 2007, 4, 5, 6).

Before estimating and selecting the techniques that could potentially be used in the incorporation of photosensitive glass, I drew up tables placed under Figure 4: Table 1.0, Figure 5: Table 1.2.0 and Figure 6: Table 1.3.0 to aid my selection. Walker, Brad. (2000/2002) argues that artists and craftspeople define art-glass into three main categories, Hot Glass (molten), Warm Glass (fusing or slumping), Cold Glass (room temperature) based on their working temperatures.

**Figure 4:** Table 1.0.0.

Traditional art-glass making techniques that I estimated to be suitable for integrating with photosensitive glass based on information from Brad Walker (2000/2003).

COLD GLASS TECHNIQUES	WARM GLASS TECHNIQUES	HOT GLASS TECHNIQUES
Pate de Verre – recycling	Kiln Casting Slumping, Mould pressing, Kiln Formed jewelry Pate de Verre Triaxials Open-face mould casting	Blowing Applied splinters Applied blobs, Applied filaments, Overlaying, Four types of Graal Incalmo, Ice-glass Fenicio
Acid Etching/cutting Hydrofluoric acid Sugar acid, Corrosion Sandblasting		Hot Casting Sand Casting Metal mould casting Furnace casting
Laminating		Mould Blowing Variety of moulds
Toughening		Murrine Mosaics
Architectural applications		Stringers
Leadlight	Addition to silver stain techniques in leadlight - shadowing	Canes Rode
		Cameos
		Bullion, Crowns, Disks
		Lamp Working/ Beadmaking Coreforming

Each of the three categories of glass shows a list of techniques applicable to its working temperature in the above table. The techniques that I estimated would be potentially suitable for photosensitive glass incorporation were taken from the above table.

**Figure 5:** Table 1.2.0.

Processes and Temperatures of Traditional Art-glass making, that I estimated to be suitable for photosensitive glass incorporation.

PROCESSES AND TEMPERATURES (Walker Brad. 2000/2003)  
Category of Art glass: Warm Glass.

	DEFINITION/ DESCRIPTION	TEMPERATURE Celsius/Fahrenheit	PHOTOSENSITIVE HYBRIDS
Full fusing	Joining two or more pieces of glass by heating until they flow together	788-843 Celsius: F.1450-1550	
Slumping	Shaping glass by bending it over or into a mould, also draping.	649-704 Celsius: F1200-1300	
Combing	Manipulating glass by raking tool across the surface of molten glass	899-954 Celsius: F 1650-1750	
Fire Polishing	Heating glass just enough to round the edges and give it shiny appearance	704-760 Celsius: F1300-1400	
Kiln casting	Fusing pieces of glass (called 'frit') or sheets inside a mould	816-871 Celsius: F.1300-1500	
Pate de Verre	Fusing a paste made with pieces of glass inside a mould.	816-926 Celsius F 1300-1500	.
Glass casting in kiln	Melting glass into a mould	816-926 Celsius F1500-1700	

This table showing the warm glass processes and their applicable temperatures was consulted when selecting the traditional techniques for my case studies. My experimental heat development range was from 490 degrees Celsius to 650 degrees Celsius, well below the recommended traditional working temperatures so as to encourage the development of colours other than red, puce and dark red and liver-red (haematone).

**Figure 6:** Table 1.3.0.

Traditional art-glass making techniques based on information from Glassway (2004) for conducting my experiments incorporating photosensitive glass with the three categories of traditional glass-making techniques.

Description	HOT GLASS [furnace glass]	WARM GLASS	COLD GLASS	HYBRIDS
Finely crushed & moulded			Pate de Verre recycling	
Coarsely crushed		Pate de Verre Triaxials	Chunk de Verre	Architectural glass
Corrosion			Etched Acid cut	
Sand Etched			Sand blasting	Etched glass
Lost wax [cire-perdu] Mould formed glass		Kiln casting Kiln forming		
Free slumping		Jewelry	Jewelry	Kiln jewelry
Mould Blown	Blowing iron			
Half mould blown	Blowing iron Half-moulds			
Graal x 4 Overlaying, Incalmo Ice glass	Blowing iron Blowing iron dipped into water			
Applied glass	Blowing iron and added blobs, filaments, splinters of glass, [fenicio]festooned threads			
Furnace cast	Scoop Sand Cast Mould cast Metal mould cast			
Gathering, wrap & Pulling	Pontil [Punty] Core formed			Pulling Stringers Wrapping cores
Gathering, Pulling Twirling	Pontil [Punty] Punty & Blowing iron			Canes, Rods, Bullions, & Medallions Mosaics ,Murini
Lampworking plus added glass filaments				Beads, Core Formed jars.

The term '*Hot glass*' is used to describe the state and temperature of the molten glass in the crucible of the glass blower's furnace. A glass blower or an artist removes this very hot slippery fluid glass from the furnace using a ladle to pour it into sand or a variety of moulds. The working temperature for Hot glass from the glass-makers furnace is 1140 degrees Celsius for the glass blower to 1200 degrees Celsius for glass casting. Descriptions of the techniques are summarized in Figure 6: Table 1.3.0 (Glassway 2004). Working temperatures for '*Warm glass*' and '*Cold glass*' categories and processes are described and summarized in Figure 5: Table 1.2.0. Brad Walker's (2000/2002) notes on Fusing, Slumping and Mould Forming Glass were of great assistance in determining my selection of traditional glass making techniques that would be suitable for photosensitive glass incorporation. Selected traditional art-glass techniques that I estimated to be suitable for incorporating photosensitive glass by experimentation were based on the working temperature of the techniques described in all three tables. Figure 4: Table 1.0.0. illustrates the selected traditional art-glass making techniques and it places them into the case study compartments according to their main categories such as Hot Glass, Warm Glass and Cold Glass.

In particular, I was interested in the ancient glass making techniques which consisted of four major manufacturing methods with many variations, both major and minor (Lois Freun 2002). This information about the ancient glass-making techniques was essential in identifying the traditional techniques to be selected. The identification of the traditional art-glass acted as an extension of my literature review of glass making and included participation in glass making workshops and demonstrations involving various techniques and processes. The four major ancient techniques were Rod and Core forming, Casting with open and closed moulds, Free-blowing and blowing into moulds and forms of various kinds<sup>10</sup>.

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<sup>10</sup> Ancient Techniques: The ancient techniques were deduced from physical examination and scientific analysis of ancient glass artifacts discovered by archeologists. A good deal remains to be learned about the actual workings of ancient glass factories and about specific glass making methods. Recent research has uncovered an unexpectedly diverse rich variety of tools, techniques

These techniques are described in Figure 4: Table 1.0.0., Figure 5: Table 1.2.0., Figure 6: Table 1.3.0. My interest in the ancient techniques stemmed from the fact that I had very limited access to a hot glass furnace and I estimated that I could experiment with some of the ancient techniques that did not require one. However, I discovered through experimentation that it was essential for photosensitive glass to be '*flamed*' or heated in the glory-hole before incorporating it into some of the techniques used in the case studies. After '*flaming*' the photosensitive glass, the experiments were set up then they were exposed to timed ultraviolet light. A range of monotone colours was established by heat development between 490 degrees Centigrade and 550 degrees Centigrade. This heat development took place in a digitally controlled electric kiln for pre-determined times. From 575 to 650 degrees Centigrade photosensitive glass becomes a bright red colour at the lower temperature and a muddy liverish red colour (haematone colour) at the higher temperature when developed in an electric kiln. This discovery meant that I would have to construct a miniature furnace for my own '*flaming purposes*' as I could not afford to hire a hot glass studio nor spend the time travelling to a hot glass studio.

### **1.9.1. Overview**

Chapter One serves to identify the starting point for the experiments and lays down the foundation for my argument. It introduces the research problem, research issues and hypothesis. The initial ideas of the likely outcomes of my research are outlined, the research justified, the definitions presented, the objectives defined and the scope of the research stated. This overview states the position from which I measured the success or failure of all the case study experiments incorporating photosensitive glass into traditional glass-making techniques. Based on my role as participant observer at the Hyaline Hot Glass Studio 2003 – 2007 and previous experience as an undergraduate art student in the

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and practices over time. Attempts have been made in contemporary practices to reproduce ancient glassware using the ancient techniques ( Fruen, L.2002), (Klein & Ward 1993, 10-13).

Clay & Glass Studio, Curtin University School of Art from 1999 to 2003, I began this research by looking at the broad field of Art Glass through to the narrow focus of the research problem as illustrated in Figure 1: Broad Field of Research to Narrow Focus of Research Problem in Background to the Research, page 4. I then looked at situating the research problem area in relation to the literature, as illustrated in Figure 2: Situating the Research Development Area in Relation to the Literature in the Background to the Research section (Perry 1998, page 5), (Love 2006).

Chapter Two discusses research issues, the literature review and what photosensitive glass is made from, its process methodology, technological and artistic development using photosensitive glass and the history of photosensitive glass. Practice-led research and practice-based research are defined and discussed. Collaboration is defined and discussed and examples of successful collaborations amongst glass artists are listed. The adaptation of 19<sup>th</sup> century alternative photographic printing techniques to new creative technologies by combining them with photosensitive glass technology of the 1950's is also discussed.

Chapter Three introduces the framework for the research and discusses the practical foundation, the theoretical foundation and the methodologies used. Why the case study method was selected and why the participant observation approach enabled the selection of suitable case studies from the traditional processes in the field of art-glass to be made. Why the experimental form of the scientific method was used to address the question of involving the observation of the phenomena associated with photosensitive glass. It discusses the approach used to define the specifics of the research problem by situating the research in its broadest context as well as finding out what sub-set the research belonged to. Chapter Three also discusses the fields that photosensitive glass is being used in, how it is being used, why it is being used and demonstrates how the research problem could be significant. It discusses the assumptions of the use of photosensitive glass in the art-glass field. It describes how the equipment used in this research was designed

and made, how the experiments were conducted and recorded, the methods used for data collection and how the data were analysed.

Chapter Four describes the planning, building and conducting of this research based on the case study methodology. The strengths of case study research and research strategy. It discusses the collaborations that I became involved in, my plan of work which includes practice-led research, the selected case studies, problem solving when designing my case studies, my role as a participant observer and volunteer assistant in a hot glass studio. It discusses participant observation research documentation and the designing of a case study Protocol for this research.

Chapter Five illustrates, describes and discusses the successful and unsuccessful scoping experiments and their outcomes in written report format. Each traditional glass-making technique was allocated a case study then the scoping experiments were recorded in the relevant sub-categories of their case studies. These sub-categories became units of analysis. Each sub-category was defined before being placed in its historical context. The seven selected case studies are listed in order of difficulty of technical application. General rules and procedures about how the research was conducted as well as the identification of a range of experimental issues were addressed.

Chapter Six introduces the successful case studies and their experiments. It further develops the outcomes of the successful scoping case study experiments identified in Chapter Five. Out of the seven selected traditional techniques for the incorporation of photosensitive glass that were presented as potential case studies, four traditional glass-making techniques produced successful outcomes from their scoping experiments.

Chapters One to Four are the introduction for the experimental research done in Chapters Five and Six.

Chapter Seven discusses the research question and summarizes the potential outcomes of the research.

The tables 1.4.0 to 1.4.6 in Figure 7 summarize the case study scoping experiments done in Chapter Five and the outcomes of the successful scoping experiments are shown in Chapter Six.

**Figure 7:** Overview of Chapter Five Scoping experiments using photosensitive glass and their successful outcomes as experiments in Chapter Six.

Table 1.4.0.

<b>Chapter Five:</b> Scoping Experiments.	Sub-categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes/ No or Other.	<b>Chapter Six:</b> Successful Experiments.	Final outcome.
<b>Scoping Case Study One: 5.1.0.</b> [Pulling and drawing out]. (Hot glass).	Sub-category 5.1.1.	Pulling Stringers, rods and canes.	Yes	Stringers	Yes
	Sub-category 5.1.2.	Making Murrine or mosaics.	Yes	Murrine	Yes
	Sub-category 5.1.3.	Pouring Medallions, or cutting rods for Bullion or Crowns.	Other/ Interrupted.	(See case study 6).	No

Table 1.4.1.

<b>Chapter Five:</b> Scoping Experiments.	Sub-categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes/ No or Other.	<b>Chapter Six:</b> Successful Experiments.	Final outcome.
<b>Scoping Case Study Two: 5.2.0.</b> [crushing and recycling] (Warm glass).	Sub-category 5.2.1.	Chunk de Verre (Large Chips of Glass).	Partially successful/ see case study Four	Nil	Nil
	Sub-category 5.2.2.	Pate de Verre. (small chips of glass).	Partially successful	Nil	Nil

Table 1.4.2.

<b>Chapter Five:</b> Scoping Experiments.	Sub- categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes/ No or Other.	<b>Chapter Six:</b> Successful Experiments	Final out come.
<b>Scoping Case Study Three: 5.3.0.</b> [Bead- making/ Flameworking] (Hot glass).	Sub-category 5.3.1.	Bead-making.	Yes	Beads	Yes
	Sub-category 5.3.2.	Button making – a bead-making process.	Partially	Nil	Nil
	Sub-category 5.3.3.	Core forming – a bead-making process.	Partially	Nil	Nil

Table 1.4.3.

<b>Chapter Five:</b> Scoping Experiments.	Sub- categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes/ No or Other.	<b>Chapter Six:</b> Successful Experiments .	Final out come.
<b>Scoping Case Study Four: 5.4.0.</b> [Kiln casting/slumping] (Warm glass).	Sub-category 5.4.1.	Kiln casting/slumping (Kiln work).	No	Nil	Nil
	Sub-category 5.4.2.	Simple open face Pate de Verre (Triaxial blending)	Yes	Yes Very successful	Yes

Table 1.4.4.

<b>Chapter Five:</b> Scoping Experiments.	Sub- categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes or No or Other.	<b>Chapter Six:</b> Successful Experiments.	Final out come.
<b>ScopingCase Study Five: 5.5.0.</b> [Furnace casting] (Hot glass).	Sub-category 5.5.1.	Sand casting.	No	Nil	Nil
	Sub-category 5.5.2.	Forcing hot molten glass into metal moulds.	No	Nil	Nil
	Sub-category 5.5.3.	Casting into a variety of moulds.	No	Nil	Nil
	Sub-category 5.5.4.	Casting/Sprinkling	No	Nil	Nil

Table 1.4.5.

<b>Chapter Five:</b> Scoping Experiments.	Sub- categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes/No or Other.	<b>Chapter Six:</b> Successful Experiments.	Final out come.
<b>Scoping Case Study Six: 5.6.0.</b> [Free blown glass & blowing a bubble into a mould] (Hot glass).	Sub-category 5.6.1.	Free blowing (Crown/Bullion or Disk).	Yes	Yes	Yes
	Sub-category 5.6.2.2.	Mould blowing	Nil	Nil	Nil

Table 1.4.6.

<b>Chapter Five:</b> Scoping Experiments.	Sub- categories of Scoping Case Study Experiments.	Description of techniques.	Successful: Yes/No or Other.	<b>Chapter Six:</b> Successful Experiments.	Final out come.
<b>Scoping Case Study Seven 5.7.0.</b> Acid etching [Hazardous] (Cold glass).	Sub-category 5.7.1.1.	Acid etching/acid embossing. (Cold glass corrosive technique).	Not attempted only discussed	Not attempted – only discussed	Nil

## CHAPTER TWO – LITERATURE REVIEW

### 2.0.0. Introduction

This chapter builds the theoretical foundation upon which this research is based. It consists of the literature review, what photosensitive glass is made from, the history of photosensitive glass, practice-led and practice-based research, and the adaptation of 19<sup>th</sup> century alternative photographic printing techniques.

### 2.1.0 Literature review

The relevant research issues were identified by using a contextual literature review (Gray and Malins 2004, 14) and systematic literature search approach as well as back tracking citations and demonstrating that they are significant. A systematic literature search included a focus on the important historical event in the art-glass area, the International Contemporary Studio Glass Movement<sup>11</sup>. The Contemporary Studio Glass Movement had its origins in postwar Europe. “*The French painter Maurice Marinot stands as a forerunner of the later movement on the strength of his productions in the 1920s and 1930s of individual vessels in thick, smoky glass, often enriched by dense internal drifts of tiny gas bubbles*” (Edwards, 1998:182).

This search through the information in the field of art-glass assisted me in focusing my research development area in relation to the literature (Figure 2). By being familiar with the background of the International Contemporary Art Glass Movement of the 1960s I was able to select a few art-glass techniques that I considered suitable for experimentation with the incorporation of photosensitive

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<sup>11</sup> This historical event can be viewed in Appendix Ai (a) (Chapter Two).

glass. Further literature searches have revealed a number of scientific papers based on the discovery of photosensitive glass, developed at Corning Glass, USA by glass chemistry researcher, S. Donald Stookey during the 1940's and 1950's. Since then a comparatively recent but significant paper '*Full color photosensitive glass*' describing the new polychromic photosensitive glasses in which the full-colour spectrum is developed by photochemical precipitation of sub colloidal silver too small to scatter light was published by S. Donald Stookey, George H. Beall and Joseph E Pierson (1987, 49, 10). This discovery of full-colour photosensitive glass is significant for glass artists. The developers of this glass state that colour may be developed in either clear or opal areas and the colours can be restricted to the surface of the glass or generated to a great depth. Prior to this new development, photosensitive glass only printed out in monotone colours after timed ultraviolet light exposure then heat developed. Unfortunately this full colour photosensitive glass is not yet available to the public. "*While studying certain silver-containing photosensitive sodium fluoride opal glasses, an unexpected and complete color spectrum was observed when a secondary ultraviolet exposure/heat treatment operation was superimposed upon the normal cycle required to produce the photo-opal. This observation led directly to the investigation reported in this paper*" (Stookey, Beall and Pierson 1978 49, (10): 5114-5123). Further scientific research has been identified in the current fields of Optoelectronic Technology. Ebendorff-Heidepriem, Riziotis and Taylor (2002, 75, 54-59) from the Optoelectronics Centre, Department of Physics, University of Southampton, United Kingdom, published a paper called '*Novel Photosensitive glasses*'. The authors of this paper researched the material properties of photosensitive glass which is of great importance to the scientist as well as the artist. A paper by Eugene Pavel (1997) on *Hyper CD-ROM: Three Dimensional Optical Memory with Fluorescent Photosensitive Glass* discusses the importance of photosensitive glass being the most secure and stable storage facility for data archiving systems such as Glass Computer Data, Archiving Systems Technology, Communications Systems Technology and Microtechnology. It discusses architectural applications, design glass applications and applications of images for

large organizations, government institutions, banks, insurance companies, space and military applications as well as many other extreme diverse applications such as text in art-glass. Gregory Fishbein (1997), a researcher at UTIAS developed a New Bragg Grating Positioner Platform. His research involved the Ultraviolet light changing characteristics of the photosensitive glass core. He developed this new device which will significantly improve the process of ‘writing’ fibre optic sensors used for research. Schott FOTORAN, the Technical Glass Division of Corning advertises photosensitive glass as a photo-etchable glass. It is a material for micro technology. *“The main difference between FOTORAN and ceramic materials is that it is pore-free. Its temperature stability and chemical resistance are notably higher than those of plastics. In comparison to metals, FOTORAN shows better corrosion resistance, is electrically insulating and has a lower thermal conductivity. Its advantages over silicon are its availability in a wide variety of dimensions; it can be structured in various geometries; and, above all, considerably higher breaking strength”*. Schott Corporation, the Technical Glass Division of Corning advertises photosensitive glass as a photo-etchable glass. It is a material for micro technology. (Schott Corporation 2002).

However, examples of the use of photosensitive glass in the field of glass art and glass design are limited. So far, three of the few glass artists, who are exhibiting glass-artwork through galleries, have been identified. They are Mary Van Cline, Luke Jacomb and Jim and Cynthia Miller of Fireweedglass. Glass artist/sculptor Mary Van Cline of Seattle, Washington State, USA has been placing photographs into the glass body of her sculptured works since 1997 using the technique that S. Donald Stookey invented<sup>12</sup>. Luke Jacomb of Auckland, New Zealand exhibited his blown glasswork incorporating photosensitive glass at the International Glass Art Society Conference, held in Seattle 2001. Steve Ringman (2000) reported *“Glass artist Luke Jacomb shows off one of the pieces he created using a new technique in which the glass itself acts as a photograph. Jacomb creates images*

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<sup>12</sup> Some of Mary Van Cline’s work can be seen at: Imago Galleries, 45450 Highway 74, Palm Dessert, CA 92260 USA. Website: [info@imagogalleries.com](mailto:info@imagogalleries.com)

*by using an unusual glass that is photosensitive*". Further information from glass Internet Bulletin Boards has not been very forthcoming. Some glass artists reported that they had tried the process but have not managed to achieve the colours that they had been promised they would. For the wider context, Edmund DeWaal (1999) argues that ceramic art practitioners are often silent about their work and that of their peers. This silence seems to have become a symbol for their seriousness as artists. My research takes a very different approach by documenting and discussing technology and process.

### **2.1.1. What is Photosensitive glass?**

As noted in the introduction of this thesis, photosensitive glass is a crystal clear glass in which microscopic metallic particles can be formed into a picture or an image by exposure to short wave radiations such as ultraviolet light (Paul 1990, 333, and Maluf 2004, 62-63 from the section on Photosensitive Glass in the Section of Scientific and Technical Terms 2003).

*"Stookey realised that he required a sensitizer which would absorb ultraviolet Light and then reduce colourless gold compounds dissolved in the glass to insoluble metal. Tin oxide functioned as a reduction agent at low temperatures, but was insensitive to middle range ultraviolet light. Stookey's important discovery was that the ideal oxide required was cerium. Cerium not only donated an electron to gold but did so at the right temperature range, and most importantly, under the influence of radiation at a more useful bandwidth. Both gold and silver were then able to be utilised. The addition of cerium as a sensitizer increases the sensitivity of the glass to a greater spread of wave lengths. Specifically, although a latent image can be formed with silver and copper without cerium, because they both have broad absorption bands in the middle ultraviolet, (around 300-350m $\mu$ ) gold absorbs only short wave ultraviolet light, ( at around 254m $\mu$ ) without cerium (Croucher 1991, 4, 14). These microscopic metallic ion nano particles are responsible for the refractive index change. When ultraviolet light passes through a negative placed onto the glass, it precipitates the particles, with the shadowed areas of the negative permitting deeper penetration into the*

glass than the highlighted areas, giving the picture three dimensions and colour; the photograph is developed by heating the glass to 1000 degrees Fahrenheit / 538 degrees Celsius (from the section on Photosensitive glass in the Dictionary of Scientific and Technical Terms 2003). Stookey at Corning developed several varieties of photosensitive glass compositions, some are available from Color Rods, in Seattle, Washington State, United States of America.

Gaffer Glass of Auckland, New Zealand makes Gaffer #080 photosensitive ruby glass available in rod form for the glass-artist. Gaffer Glass describes photosensitive glass in their catalogue of glass rods for glass blowers as a transparent “flashing” colours glass. It is classed as thermal contraction compatible (tested with a trident seal) with typical generic lead and soda lime based glasses and is internationally recognised. Gaffer recommends using the flashing colours such as Photosensitive Ruby #080 and silver photosensitive glass with Gaffer \ Batch or Gaffer Eco Batch for a perfect thermal and viscosity compatibility match. Gaffer provides an instruction sheet regarding the optimum procedure to follow when using Photosensitive Ruby #080 and photosensitive silver glasses.

### **2.1.2. Properties of Gaffer#080 photosensitive ruby glass**

Gaffer #080 photosensitive ruby is in most respects like a normal soda lime glass in its physical properties regarding devitrification tendencies, ease of polishing and forming (Croucher J.Gaffer Glass 2011). *“Their composition is very similar to ordinary silicate glasses. It is important that they do not contain oxides which cause the absorption of short wave radiation, or additionally, in the case of gold and silver glasses, substantial reducing agents, which will cause the precipitation of the metals before ultraviolet exposure and development by heat”*(Croucher 1991,9).

### **212a Glass structure**

*“The colour and the glass structure is entirely stable after being formed, exposed and developed. After development no end of extra ultraviolet exposure will change anything. It is a non reversible process. Exposure to daylight before development can ruin the photosensitivity of the glass”* (Croucher J. Gaffer Glass 2001).

In a personal telephone communication with John Croucher he assured me that there can be some devitrification as is normal with other soda lime glasses. When I asked if the photosensitive art-glass object would become matt when cold polished his answer was that it would not. When fire polished the colour of the object will not change colour not would it devitrify. Colour change only occurs when the glass-art object is totally melted down. Photo sensitive glass-art objects are totally food-safe.

### **212b Etchability**

Foturan, a silver photosensitive glass is stated to be twenty times more etchable when exposed and developed than unexposed and developed. Gaffer Photosensitive #080 ruby shares almost nothing with the etchable photosensitive glasses. These etchable photosensitive glasses are an entirely separate family of lithium silicate phase glasses. The only common thing that they do share is that they are activated by similar photosensitive principles (Croucher, J. Gaffer Glass, 2011).

### **Photographic resist materials**

*“A large number of resists were experiments with: bromide, Xerox on polyester, Letratone and Letraset, reverse negatives on polyester, black and white film negatives and colour negatives. As well, simple masking tape and black felt tip pens were employed. In all cases images could be developed using these resists except in the outstanding case of colour negatives and colour 35 mm slide transparencies, even after 24 hours exposure time. These latter two mediums are obviously almost totally opaque to ultraviolet light at these frequencies. Definition achieved was not as fine as in conventional photography, but perfectly adequate. It was felt that reverse negatives on adhesive backed polyester offered the most promise, particularly when fine definition was required. However, black felt tip pens gave the most freedom, especially where simple fine graphics were concerned” (J.Croucher, 1991, 37).*

My future plans are to expose blown photosensitive glass objects to ultraviolet light using a variety of sunscreen lotions as masks. Lack of time has prevented me from undertaking a sequential series of these potentially interesting experiments.

### **2.1.2c Exposure under ultraviolet light**

Exposure wave length of ultraviolet light for Gaffer #080 ruby photosensitive glass is between 300- 350 m $\mu$  preferably peaking at 320 m $\mu$ . Sun light can work particularly at sunburn strength but the results are variable. *“The exposure of photosensitive glass is in many respects similar to that of ordinary photographic material. It differs mainly in the fact that exposure requires short wave radiation, and usually requires much more time. Whilst the radiation may be of the X-ray or gamma variety, typically the range of wavelengths from 280 – 350 m $\mu$  is most frequently used. Mercury-arc lamps, or fluorescent tubes emitting in this range will prove effective. Because the final form of the image may be three-dimensional, it will be necessary for the exposure to be carried out with parallel rays which act perpendicularly to the glass surface. (In all cases the character of the image is a function of the quanta of effective radiation absorbed by the primary light sensitive ingredient) No image is visible after exposure, which is why it is called a latent image”* (Croucher, J.1991, 23). At the ultraviolet exposure step FORURAN glass is exposed to an ultraviolet light at a wavelength between 290-330 m $\mu$  This material combines the unique glass properties such as transparency, hardness, chemical and thermal resistance and the opportunity to achieve very fine structures with tight tolerances and high aspect ratio (hole depth width). Smallest structures of 25 m $\mu$  are possible with a roughness of 1 m $\mu$ .

### **2.1.2d Heat development using Gaffer #080 photosensitive ruby glass**

*“Before heat treatment, the glasses are substantially colourless (although silver and copper containing glasses may exhibit a pale yellow or blue colour respectively). The rate of heating and cooling, within reasonable limits, does not affect the development of the latent image, and in addition the process can be interrupted and resumed at any point. The development of the image takes place very slowly (several hours) at the annealing temperature of the glass at a moderate rate ( one hour) midway between the annealing point and softening temperature, and rather rapidly (10 minutes) thereafter, at the softening range. The limiting factor in terms of the viscosity chosen to develop at will be mostly concerned with avoiding undue deformation of the glass article in question. Obviously the less deformation required, the more time that must be allowed for development. The temperature and time of the heat treatment will depend upon how greatly the metals in the glass have been affected by the irradiation. With glasses containing gold in particular, orange and red colours, characteristic of strong exposures,*

*develop more rapidly than purple and blue. Furthermore the dept of penetration of the colour increases with time and temperature, thus increasing the intensity of the colour. Contrast is boosted by increased development time and temperature as well” Croucher (1991, 27).*

### **2.1.2e Depth of image penetration (photographic process).**

*“The depth that the radiation penetrates into the glass is not only a function of time, but is determined by the spectral transmission of the glass, and the wave lengths of the radiation source employed. Various impurities inhibit transmission, so that the depth of the image can range from just the surface on up to 50mm deep. Radiations in a range below 300m $\mu$  will cause the image to develop only on the surface whereas if all radiations below 340 m $\mu$  are eliminated with a filter, a frequency where the glass is much more transmissive, then a much deeper penetration will result.” (Nebrensky 1965, 179) cited by Croucher (1991, 24).*

#### **What is the loss of UV with depth?**

*“In the case of gold/barium photosensitive glasses, a short exposure time and subsequent heat treatment, allows only a small number of particles to grow to larger dimensions, giving a blue tint. With longer exposure times, a large amount of active centres, and consequently a larger amount of smaller particles are formed, resulting in red colouration. As the ultraviolet radiation intensity decreases with the depth of penetration into the glass, the undermost layers of the latent formed are usually bluish, and the overall time of the whole thickness becomes a purple of an intense hue. Increasing the radiation dose results in a read layer of increased thickness, the effect of the blue layers is weakened, and the colour becomes redder. With a reasonable intensity of radiation, most latent images can be formed inside of one hour. Stookey claims an exposure of the order of 2 milliwatt minutes per square centimetre in the effective wave band is required to produce a medium density. An average photographic negative will filter the radiation, and so 3 to 10 times this exposure may be needed. Photographic negatives tend to filter out transmissions shorter than 300m $\mu$ ” (Stookey, 1949, 858) cited by Croucher (1991, 24).*

## Technical Instructions on the use of photosensitive glass from Gaffer Glass Ltd.

### **Gaffer® Photosensitive Glasses**

For the first time, Gaffer Coloured Glass offers photosensitive glasses suitable for use as a casing glass for the studio glassblower. Although noble metal photosensitive glasses were developed by Dalton and later Stookey, at Corning, during the Second World War (and kept under wraps by the US government until the war ended), they were never much exploited by Corning. They offered them largely as a novelty glass in the 1950's and 60's.

Gaffer Glass has reworked the original recipes, in order that the glasses will be compatible with typical soda lime glasses used by the studio artist. Particular attention has been paid to aligning the properties of expansion, viscosity and durability.

### **Properties and Application**

Gaffer photosensitive glasses can be used in the same way as any other casing glass, either as an inner or outer casing, or as an interlayer. They are soft, and easily worked. In order to exploit their properties, however, these glasses must be able to be exposed to ultraviolet light in the finished piece. Think of the glass rod as virtually like filmstock. It must be kept in the tube we supply until ready to use for blowing. After finishing a blown piece that also must be kept in the dark until it is ready to be masked and then exposed and developed.

Although photosensitive glasses are not anywhere near as sensitive as film, the ambient levels of UV light in a room will still be sufficient to "spoil" the glass after a day or two. Avoid direct sunlight. A "spoiled" glass, however, simply becomes an ordinary gold ruby or silver yellow, on being reheated, so is not completely wasted.

### **Exposure**

The exposure of photosensitive glass is in many respects similar to that of ordinary photographic material. It differs mainly in the fact that exposure requires UV radiation, and usually requires considerably more time. The wavelength of light required is important, being between 300-350nm, and preferably peaking at 320nm. Sunlight can work, particularly at sunburn strength, but the results are variable. More consistent results are obtained by the use of commonly available fluorescent suntan tubes. Philips TLK 40W/10R low pressure mercury vapour fluorescent tubes are ideal. They are available in 600mm (2 foot) lengths. Other suntan tubes offer similar specifications. They should all be branded UV-A.

Note: Not all UV lamps are the same. Some lamps for instance, used for curing silk screening dyes or photo printing etc. may have the wrong wavelength for this application. Exposure at a distance of 100-150mm (4-6 in) for about 20-40 minutes is sufficient for most effects. An even exposure of a vessel can be achieved with an old record turntable. With the gold ruby glass, short exposures will give blue through to purples; longer exposures will give a true ruby. Increasing exposure with silver based glasses results in an increasingly deeper and stronger yellow colouration. The colours produced, and the density of the hue, depend on exposure time and intensity, but importantly, also on development temperature, and time. After UV exposure, only a "latent image" results, which is not visible. Development by heat is still required.

### **UV Resists.**

Anything which resists UV light can act as a resist or negative. For photographic resolution the most efficient material is adhesive polyester as a reverse negative, available from specialist photographic suppliers. However, anything which can stop UV is suitable. Felt tip pens, Letratone, bromides, masking tape etc. are all effective to varying degrees.

### **Development**

Unlike ordinary film, which requires chemicals to develop the image, photosensitive glasses simply require heat. For silver glasses the "latent image" will develop in 3-4 hours at 475-525°C (886-976°F) For the ruby glass a higher temperature of 520-575°C (968-1058°F) is required over a similar period of time. The higher the temperature, the quicker the development. The term "latent image", refers to the fact that simply exposing the glass to UV light will not make visible the colour. The colour centers are "latent" until developed by heat. If the glass is slumping, then simply lower the temperature, and take more time for the image to develop. Only by heating to the correct temperature range, for long enough, will the latent image reveal itself or strike.

As with exposure, short heating times, and low temperatures, will produce blues and purples with the gold ruby: high temperatures for longer periods promote the true ruby shade. The silver yellow deepens in hue with long exposure and development. Copyright: Gaffer Coloured Glass Ltd.

The chemical structure of photosensitive glass, printed out below was freely available from Material Safety Data Sheet, Spezialglas AG, 01-09-1998 and is Copyright © Californian Institute of Technology, 1999, 2000. Weyl (1967) suggests that the Ce and Ag are the two critical components and the rest is a base glass.

*Schott FOTURAN® Photosensitive glass is manufactured by Mikroglas FOTURAN® Fabricator, mgt mikroglas technik AG, Galileo-Galilei-Str 28, 55129 Mainz, Germany EU. Tel: +49-6131/5550-0. Fax: +49-6131/5550-52. <http://www.mikroglas.com>, [info@mikroglas.com](mailto:info@mikroglas.com)*

*Mikroglas FOTURAN® Information (English)*

*FOTURAN® Processing and Properties Information*

*FOTURAN® is a photosensitive glass which enables it to be structured for a variety of purposes. This material combines the unique glass properties (transparency, hardness, chemical and thermal resistance, etc) and the opportunity to achieve very fine structures with tight tolerances and high aspect ratio (hole depth/hole width). Smallest structures of 25 µm are possible with a roughness of 1 µm.*

**UV- Exposure:** *In the exposure step, FOTURAN® glass is exposed to ultraviolet light at a wavelength between 290-330 nm. It is possible to illuminate material thicknesses of up to 2mm. An energy density of approximately 2 Joule/cm is sufficient to structurize a 1 mm thick FOTURAN® plate.*

**Heat Treatment:** *With the UV exposure step silver atoms are formed in the illuminated areas. During the heat treatment between 500 and 600 degrees Celsius the glass crystallizes around these silver atoms.*

*Ingredients Data:*

*Product Name: FOTURAN®*

*Manufacturer: Schott Glass Corporation, Technical Glass Division.*

*Chemical Name: Inorganic Glass*

*C.A.S. Number: 65997-17-3*

<i>Boron Oxide</i>	$B_2O$	1%
<i>Potassium Oxide</i>	$K_2O$	1-20%
<i>Silica</i>	$SiO_2$	80%
<i>Aluminum Oxide</i>	$Al_2O_3$	1-10%
<i>Sodium Oxide</i>	$Na_2O$	1-10%
<i>Zinc Oxide</i>	$ZnO$	1-10%
<i>Lithium Oxide</i>	$Li_2O$	1-10%5
<i>Cerium Oxide</i>	$CeO_{2-Ce^{++}}$ or $Ce_2O_3-Ce^{+++}$	1%
<i>Antimony Trioxide</i>	$Sb_2O_3$ or $Sb_2O_4$ or $Sb_2O_5$	1%
<i>Silver Oxide</i>	$Ag_2O$	1%

*Melting point: 659 degrees Celsius Density: 2.37 gm/cm<sup>3</sup>.*

*(source: Material Safety Data Sheet, Deutsche Spezialglas AG, 01-09-1998).*

*Copyright © Californian Institute of Technology, 1999, 2000.*

The Methodology, designing the experiments, designing the equipment for the experiments in my research and meeting the objectives are discussed in Chapter Three.

### **2.2.0. The history of photosensitive glass**

During the 1950's and 1960's Corning Glass made photosensitive glass available as a novelty glass but it was not exploited further (Stokey, S.Donald 1949, 856), (Blakeslee A.L.1947). His invention was not announced publically until ten years later on June 1<sup>st</sup>, 1947, (Paul 1990, 333) from the section on Photosensitive glass, Chemistry of glasses in the Dictionary of Scientific and Technical Terms.

Photosensitive glass was kept a secret until the end of World War II. In the section on photosensitive glasses in the Dictionary of Scientific and Technical Terms

(Parker 2003) states that it is believed that one of the reasons between the time of inventing photosensitive glass and the delay of ten years before it was announced to the public was because of its military applications. It was discovered that it was possible to send military messages in the glass body by exposing images and words into the glass using ultraviolet light. These messages remained hidden until the glass was heat developed at a high temperature in an electric kiln (Garbowski, B.J. 1978). Paul (1990, 333) states that only large commercial glass factories produced photosensitive glass because of its high cost. In the 1980s, individual artists owning smaller studios created experimental works in blown photosensitive glass in their hot glass studios. Therefore, to date, only a few individual artists know the techniques of achieving good results when using photosensitive glass. However, innovative use of photosensitive glass continues to be and has been researched, documented and published in the scientific literature.

I argue that there is therefore a potential for further research work in this art glass area despite the high cost of the glass and labour intensive work load.

Materials research has a contextual place in creative design practice. Materials research can contribute to new innovative industries in the long-term. This research has therefore concentrated on examining and documenting photosensitive glass as a case study of materials research for art practice (Fazackerley 2005).

### **2.3.0. Photosensitive glass process methodology**

The most common process for using Gaffer #080 ruby photosensitive glass is by using an image negative (like a stencil) to control glass exposure. The ideal ultraviolet light exposure wave length should be between 300-350 m $\mu$ , with 320 m $\mu$  being optimum.(Paul 1990, 333). These exposure wave lengths are confirmed in the Gaffer Glass Instructions. The development or '*fixing*' is done with heat in an electric kiln over many hours. When the glass is heated the latent image is converted to a visible image through photo excitation (Maluf 2004, 62-63), from

the section of Photosensitive glasses, Encyclopaedia Britannica, and The New Encyclopaedia Britannica v.8 Macropaedia Ge-Hu, 1974, 194-209. Particles of silver or gold, invisible to the naked eye are within the body of photosensitive glass. These microscopic particles move and grow when heated to form the photographic image which is considered to be the most durable photographic medium known. When heatdevelopment is completed, the photographic image is not on the surface of the glass but within the glass itself. The glass must be exposed under ultraviolet light, heated then annealed under conditions as dark as possible. The final image is permanent and can vary in both colour and opacity depending on exposure and fixing time and temperatures. As the glass becomes increasingly opaque it also will be more vulnerable to Hydrofluoric acid, expanding the creative possibilities. As with film, the behaviour of photosensitive glass is the result of silver (or gold) ions reacting to light<sup>13</sup>.

My research is presented as case studies that have been analysed, and the experiments have been documented to identify methods and processes that demonstrate the potential of photosensitive glass as an art medium. This research demonstrates a changed dynamic, where experimentation can take the lead and open up a new avenue of special art-glass. The practical issues are how and where I did the experiments and how many experiments I undertook. The issue of control experiments and what variables I introduced to the experiments were decided upon. The research styles of data documentation suitable to this research were made once the design of data collection was decided upon.

### **2.3.1. Practical issues**

A practical problem solving approach was taken and has built a foundation upon which my research was based through experimentation to identify research issues. My experimental research builds on Donald Stookey's initial inventions and experimentation (Stookey, S.Donald, 1949).

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<sup>13</sup> Taken from a description of Photosensitive glass in the Dictionary of Scientific and Technical Terms (Parker 2003).

### 2.3.2. Theoretical Issues

The issues of practice-led research and practice-based research are discussed and the differences between the concepts are defined. The theoretical framework used in my research is grounded in the broad field of art-glass. The focus of my research is the narrow field of photosensitive art-glass. My investigation was practice-led research using an experimental scientific methodology involving sequential change. In *'keeping up with the field'* with the idea of developing my research methods, I took part in the three week online discussion workshop on 'Practice-Led Research in Art, Design and Architecture' on the AHRC site July 2006.<sup>14</sup>

Jolly (2007) states that a practice-led research thesis is based on the researcher's development of an appropriate experimental and analytical methodology, specific to the medium in which the practice takes place. It is grounded in an understanding of the historical and theoretical disciplinary context in which it is located. Nimkulrat (2007) emphasizes the importance of interplay between the researcher-practitioner and the artistic work in progress. Practice in practice-led research is conscious exploration with the knowledge involved in the making of artifacts. Documentation of art practice can be used as research material.

The article states that there are two principal aspects of documentation in practice-led research: phases of documentation and the role of documentation within the overall research process. The role of documentation may be underestimated in practice-led research. It connects practice with the world of research<sup>15</sup>. It can help in explaining how practice-led research can be carried out by making it an accessible experience and by making it discussable in the context of disciplined inquiry.

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<sup>14</sup> [http://www.archive.org/details/ReviewofPractice-led ResearchInArtDesignArchitecture](http://www.archive.org/details/ReviewofPractice-led%20ResearchInArtDesignArchitecture).

<sup>15</sup> The role of documentation in practice-led research 2006.

<http://jrp.icaap.org/index.php/jrp/article/view/58/85>.

### **2.3.3a. Differences between practice-based and practice-led research**

The terms ‘practice-based and practice-led’ research are often used as interchangeable. The distinction between the two can be summarized as follows:

*“If a creative artifact is the basis of the contribution to knowledge, the research is practice-based. If the research leads primarily to new understanding about practice, it is practice-led (Creativity and Cognition Studies 2009).*

### **2.4.3b. Definition of practice-led research**

*“If the research leads primarily to new understandings about practice, it is practice-led” (Creativity and Cognition Studies 2009).* The doctoral theses that emerge from this type of practice related research are not the same as those that include artifacts and works as part of the submission (Creativity and Cognition Studies 2009). The primary focus of my research is to advance knowledge about the potential of incorporating photosensitive glass into the selected traditional glass-making techniques through sequential experimentation. My research-led practice consists of the results of the various experiments and their outcomes and how they could be applied and does not include artifacts and works of art as part of this submission. This thesis is the documentation of my research-led practice. The knowledge gained through doing the experiments will be applied to my own creative art-glass work in the near future. The application of the knowledge that I have gained through doing this research will be available to all glass-artists without charge. This thesis will be available as an electronic file or multiple files on an open access server so that it can be freely downloadable to anyone who is interested in using photosensitive glass as an art-glass medium.

### **2.3.3c. Definition of practice-based research**

*“If a creative artifact is the basis of the contribution to knowledge, the research is practice-based”.* (Creativity and Cognition Studies 2009). Lelia Green (2007) defines practice-led research as being a difficult concept. She states that practice-led research is subject to its own standards of rigor and validity, is assessable according the assessments of ‘good’ or ‘bad’. It is non-quantifiable but is

experiential and qualitative and is the only methodology available through which to pursue some research questions. Green (2007) argues that while much art is created for reasons other than a conscious research process, this is not the case for a practice-led researcher wishing to establish bona fides in terms of the rigour and validity of their work. The record of the practice-led research becomes an important element of the rigour associated with a conventional qualitative research project. Green (2007) writes that one of the arguments is that the research should not only be done but seen to be done and should also be shown to be done. The evaluation and celebrations of practice-led research are made by those who seek ways to justify a dividing line between art-as-itself and art as practice-led research. Ways to differentiate the researcher who explores research questions through practice-led methodologies and creates new knowledge that might take artistic form are needed from the ways an artist who creates a new work without a conscious engagement with research. Green (2007) cites Stapleton (2006) as stating that the ways in which practice-led researchers typically ‘code’ their research practice is through documentation and routes that chart the journey from research question to finished practice-led research artwork output. Carefully-chartered research development, recorded in a way that reflects the progression practice-led research over the period of investigation, allows the assessor to ask questions to evaluate rigour and while rigour is necessary to meet the full requirements of practice-led research, it is not sufficient. Validity is important (Green 2007).

Valid research in practice-led terms can be seen as addressing an issue which is of relevance to the artistic community for which the research is taken. New ideas and investigations are not precluded but justification for a new space or area must be made by stating what has gone before and why this new research is relevant. By this manner the research follows established protocols from both scientific practice and the humanities that see research as ‘*standing on the shoulders of history*’ and establishes the boundaries of what is known at the start of the project and demonstrates how more has been discovered and communicated at the end of

the research (Green 2007). Hollbrook, St. George, Ashburn, Graham and Lawry (2006) are cited by Green (2007) as stating that the practice-led paradigm creates new knowledge and successfully convinces assessors of this fact. Green (2007) cites Haseman (2006) as suggesting that it is time to recognise practice-led research as a research paradigm that is additional to quantitative and qualitative methodologies. Green (2007) states that for the first time in Australian research history, practice-led research has been allocated an arena in which its unique approaches and advantages can be appropriately explored. *“The RQF Assessment Panel 13 (DEST, 2006) focuses on the ‘Creative arts, design and built environment’ and for the first time sets in motion the action research cycle which will enable assessors and assessed to refine their understandings of practice-led research in Australia”*.

#### **2.3.3d. The scope of practice-led research<sup>16</sup>.**

*“The professional disciplines of art, design and architecture have many differences but all share a tradition of situating learning and scholarship in a professional practice setting. ‘Practice-led research’ can be thought of as a natural extension of this principle since many academics in these fields see practice as the natural arena for inquiry and the methods of practice as methods of inquiry. The expressions, ‘practice-led’, does not describe a single set of ideas about research. Its meaning varies with discipline, location and person and it varies with the questions that are investigated. Its value is to indicate research practices, emerging from Art, Design & Architecture (ADA) and other creative disciplines, that complement methods of inquiry adopted from the humanities and sciences”*(Practice-Led Research in Art, Design & Architecture Review Report 2006). The term ‘*practice-led*’ research is used to describe a great diversity of practices and methodologies, as well as giving rise to a good deal of debate. It is a relatively new area of research that has yet to gain a ‘*canon*’ of methods and exemplars. Practice-led research has connections to many other disciplines and may draw on methods and ideas from across the natural and social sciences and

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<sup>16</sup> The Rust et al/AHRC report summary on the workshop 2006, 10.

the humanities (Review of Practice-led Research in Art, Design & Architecture. 2006).

The research problem of how traditional art-glass making techniques can be modified to incorporate photosensitive glass to enable the glass artist/designer to take advantage of its special properties has been dealt with by situating the research problem in its broadest context (Art-glass) and describing in which subsection it fits then describing the specifications of the research problem in general terms.

#### **2.3.4. Discussion**

There appeared to be a gap in the field of glass design where photosensitive glass is concerned. My research was experimental and materials based. It combined art, science and alternative photographic printing techniques. The outcomes are an original contribution to the knowledge in creative glass production. This occurred while I developed ideas during the scoping experimental phase. The outcomes of this materials research might contribute to new innovative industries; lead to products for new audiences as well as current audiences; and inspire new work with potentially new economic outcomes. So as to have significance outside my own interests this research will contribute to the knowledge and the skills of the glass designer/artist as well as the architect/designer wishing to extend their knowledge in the field of glass art. A glass artist/designer will not need to have to be able to blow glass to use these newly researched techniques. Access to a hot glass furnace and a glassblower should suffice. I believe a crucial point is that initial experimentation is necessary when using photosensitive glass and this belief maybe part of the reason that artists have not adopted its potential as an art medium for incorporating photosensitive glass into their particular favourite glass-making techniques.

## 2.4.0 Alternative photographic techniques

The adaptation of 19th century alternative photographic printing techniques to new creative technologies by combining them with photosensitive glass technology of the 1950's, was a way of expanding the boundaries of glass-art and photographic printing technology and could result in the design of a wider range of glass processes. This adaptation of these old technologies to modern creative practice required an innovative and entrepreneurial application of materials research, based on experiments grounded in art and design practice. Any newly developed hybrid technological processes are seen as having characteristics and qualities that have value in their own right rather than being considered as a means to an end, or a way of producing a simulation using computer aided design. (Thirkell and Walters 2007, 232-245). Alternative photographic techniques developed by nineteenth and early twentieth century art and design practitioners have been given a new perspective in terms of their application to photosensitive glass-art and technology (Petrie, 2007, 1). While experimenting with his discovery of photosensitive glass, S.Donald Stookey exposed a photograph onto his photosensitive glass using ultraviolet light and heat development. The result was that the photographic image was permanently imbedded within the glass body.

Thirkell and Walters (2007,232) state that Art and Design practitioners who are expanding the boundaries of their work are able to develop novel strategies and processes because they often adopt approaches to new design technologies that are conceptually different from those employed by industrial designers and engineers. The combination of old and new technologies often presents the possibility of many new relationships between making, revealing and knowing. The way that these '*new technologies*' are applied often make practitioners of the arts to question and challenge accepted notions of '*best practice*' in their field. Some early critics (Cooley 1980, 100) of computer aided design feared that the introduction of the new computerized technologies posed a threat to human creativity and would also result in the loss of valuable tacit knowledge of physical materials and processes

possessed by skilled makers (Thirkell and Walters 2007, 235). Critic Todd Hewitt (2007) suggested that using computer aided design programs would lead to de-skilling and that creativity would be reduced by the boundaries of the systems and equipment specified for them.

#### **2.4.1 Innovative combination of three old technologies**

To compress time, the adaptation of old photographic technologies such as Gum Dichromate printing and Cyanotype printing to modern creative practice required some innovative applications of the simple images. I realized that I would need to adapt them to modern digital technological processes that would facilitate the incorporation of photosensitive glass into the selected traditional glass-making techniques. By using a Umax Power Look II scanner to shorten the time needed, I digitally manipulated the basic images using Photoshop 6 before their application onto photosensitive glass to re-create the image and reduce the time consuming manual stages of the old alternative photographic techniques. The adaptation of these old technologies to printing and exposing an image into photosensitive glass required an essential understanding of their original application before experimentation with the digital computerized technological images was undertaken. My experience with the 19<sup>th</sup> century alternative photographic printing techniques came about when doing an elective unit during my undergraduate years in design photography. This practical knowledge is necessary to inform the creative development and to avoid any problems in the physical realization of the designs (Marshall 2002, 24). Thirkell and Walters (2007, 233) suggest that the historically old photographic techniques might be considered to be to some extent analogous to today's 3D scanning and 3D printing technologies. Working with historical processes gives one the freedom to work with a broad range of photographic printing papers as well as other supports such as fabric, glass and metals concludes Hamish Stewart (2004-2006).

## **2.5.0. Practical approaches**

The term '*Alternative*' refers to the type of photographic processing which began the whole history of photography, before pre-coated resin coated papers, before colour printing and before computer generated images (Tarlu 2003). An elective unit on Alternative Photographic Printing Processes was part of my undergraduate degree in Design Photography. My particular interest lay in printing a photograph on glass. So as to achieve this objective I enrolled for some Art-glass units in the Department of Art at Curtin University of Technology, Bentley, Perth, Western Australia. I managed to achieve my objective but was soon bitterly disappointed when the photographic portrait I had put on sandblasted glass peeled off after six months. My glass blowing lecturer informed me that a 'special' glass called photosensitive glass would allow me to place a photograph into the body of glass and that it would be as archival as the Daguerreotypes of the 1840s that were printed on a piece of mirrored glass surface treated with a light sensitive chemical solution. For my honours degree in Design, my major project of placing a photograph into the body of the glass was successful. The details of the composition and the processes involved in placing photographic images into photosensitive glass will not be covered in this thesis.

### **2.7 1. Overview of Chapter Two**

In this chapter I discussed the identification of research issues through a contextual literature review, the definition of photosensitive glass, the history of photosensitive glass and its accidental discovery by a glass chemist working at Corning Glass Works. Photosensitive glass process methodology from the specifications of the problem in general terms and how and where I did the experiments and how many experiments I did. The research styles of data documentation and my method of data collection were addressed. The theoretical framework used in my research is grounded in the broad field of art-glass. The theoretical issue of the differences between practice-based and practice led-research concepts were defined. Alternative photographic techniques and their

adaption from late 19<sup>th</sup> century printing processes to modern creative practice, the innovative combination of three old technologies, such as gum dichromate printing and Cyanotype printing processes to a modern digital technological application for my research were mentioned. The methodology, designing the experiments, designing the equipment for the experiments in my research and meeting the objectives are discussed in Chapter Three.

## **CHAPTER THREE - RESEARCH STRATEGIES**

### **3.0.0. This chapter introduces the framework for the research and discusses:**

- The practical foundation.
- The methodologies used in this research.
- The approach used to define the specifics of this research problem.
- How photosensitive glass is being used and why it is being used demonstrating how the research problem could be significant.
- How assumptions about the use of photosensitive glass in the art-glass field were uncovered.
- How the experiments were designed.
- The description how the equipment used in this research were designed and made.
- How the experiments were conducted and recorded, the methods were used to collect the data and how the data was analysed.
- How the data were presented so that conclusions could be drawn.
- The description and acknowledgment of the limitations of my research (Bastalish 2005, 1).
- The issue of how the incorporation of photosensitive glass into traditional art-glass making techniques could be a catalyst for innovation and the problems that were encountered when trying to answer this question
- Why the case study method was selected.
- Why the participant observation approach enabled the selection of suitable case studies from the traditional processes in the field of art-glass
- Why the experimental form of the scientific method was used to address the question of involving the observation of phenomena associated with photosensitive glass.
- The formation of an hypothesis concerning the phenomena then experimentation to demonstrate the truth or falseness of the hypothesis as

described in the section for the scientific method, Britannica Concise Encyclopaedia (2009, 1-30).

### **3.1.0 Theory, materials, equipment and research methods**

#### **Theory**

As already stated the theoretical framework used in this research was grounded in practice and based on the experimental form of the scientific method (Allison, O'Sullivan and Owen 1996, 7). In addition to experimentation, case study, participant observation and collaboration with other glass artists as methods for collecting data for this research has been used. This research brings together science, technology, and alternative photographic printing processes in art-glass design and art-glass practice. By blurring the boundaries between the different areas, the boundaries become the foci for new artistic and theoretical potentialities. The processes have been documented in the appendices of the thesis so other makers can use the information and adapt the findings for their own purposes

#### **Glass Materials used**

The glass materials used in this research are Gaffer #080 Photosensitive ruby glass, Gaffer #101 Opal white glass. Other art-glasses compatible with photosensitive glass used were the soda lime furnace glass batch used in the furnace at Hyaline Hot Glass Studio and Spectrum #96 glass rods.

#### **List of Equipment needed for the photosensitive glass experiments**

The following list of instrumental equipment used in the research experiments was selected and validated for the measurement of the case study experiments:

- UMAX PowerLook11 photographic scanner
- Dell computer
- Adobe Photoshop 6 computer program
- Quark Express 4.00 program

- A Hewlett Packard Desk jet printer 1200 Business Inkjet
- A custom made Ultraviolet light box – 1 m<sup>2</sup>.
- Paper and/or tin foil cup-cake holders.
- A Venco electric potters' wheel
- A Kodak A1 Red Light – 15-watt bulb darkroom light
- Two 20watt NEC uv-a black ultraviolet fluorescent light tubes and frames for the ultraviolet light box
- A countdown timer from Tandy Electronics
- An Electric Kiln with a Harco digital controller
- A Flat-bed kiln with a Harco digital controller
- A custom made Miniature Furnace fired by 9 kg LPG gas cylinder designed and constructed for the research project
- Bead-making tools and equipment using LPG and an oxygen cylinder.

### **3.1.1. Definition of Experimental research**

Experimental research tries to the answer the question '*what if*' when a new element is introduced into a situation by a researcher in order to make an observation and argues that the purpose of an experimental research is to identify causal connections (Allison, O'Sullivan and Owen 1996, 7-29).

### **3.2.0. Pre-experimental data**

The pre-experimental data collected for this research enquiry were questions directed at persons with similar interests in art-glass production. No formal questionnaires were designed or distributed. The majority of questions were informal enquiries to members of forum-like groups and glass bulletin boards on the Internet throughout the duration of my research. Expert help was enlisted from the technician in the workshop of Clay & Glass as well as from the woodwork facility at Curtin University to build the ultraviolet light housing box. Designing appropriate firing programs was aided by consultation from Firing

*Schedules for Glass: The Kiln Companion* by Graham Stone 1999. Advice as to how to go about designing the experiments was obtained from many personal and professional sources. Questions regarding the instructions for using the photosensitive glass were put to one of the manufacturers of the glass in Auckland New Zealand. In reply an instruction sheet accompanied the first purchase of a photosensitive glass rod. Further questions were asked of the second photosensitive glass rod distributor in Seattle, USA. Questions were put to the distributor not the manufacturer of the glass in Germany (because I cannot read nor understand the German language) and I needed to understand and compare both sets of instructions. Enquiries were made regarding the photosensitive glass workshops planned for the GAS Conference in Seattle on 12<sup>th</sup> June 2003, however no results regarding how the glass was used in the workshop was received. There were, in general, difficulties in finding people who had actually used photosensitive glass successfully. All information received was filed and analysed before the research commenced.

### **3.2.1 Designing the Scoping experiments**

The technical issues of designing the equipment/apparatus that was needed to execute the scoping experiments, and the question of the number of scoping experiments to be made was addressed. Experiments based on the successful outcomes of these scoping experiments were then designed.

### **3.2.2. Definition of Scoping experiments**

It was confirmed in a personal communication with Dr.P.M.May, Professor of Extractive Metallurgy, Murdoch University, Perth, Western Australia, (23 July, 2006) that scoping experiments are used to test the range of the conditions for the best experimental effects. He advised that scoping experiments to refine procedure be attempted before defining the basic variables. Once the variables have been defined, to only change one variable at a time in an experiment is important.

### **3.2.3. Selecting the experimental variables**

The key variables in experimental research are of two kinds – the independent variable and the dependent variable. The dependent variable is the phenomenon that appears, disappears or changes as the independent variable is altered (Allison, O’Sullivan and Owen 1996, 7-29).

In this work, the independent variables were:

- The exposure times of each experiment using photosensitive glass relevant to its case study techniques
- The temperature that the photosensitive glass experiment is fired to in the kiln
- The length or rate of the time that the experiment is held (soaked) at a designated temperature in the kiln
- The type and amount of coloured glass added to the photosensitive glass experiment
- The thickness or size of the chips of photosensitive glass in each case study experiment.

The dependent variables were:

- The colour and intensity of the developed photosensitive glass in each case study experiment.

So as to be able to predict an outcome, some variables were controlled and some were manipulated (Allison, O’Sullivan and Owen 1996, 7-29).

It was through scoping experimentation with each case study and its sub-categories that the length of exposure time was decided upon for the timed ultraviolet light exposures. Once the ultraviolet exposure times had been established, the designing of the kiln firing programs for heat development was made and adjusted using Graham Stone’s 1999 Kiln Firing Schedules for Glass programs. Some of these programs were re-adjusted according the specific experimental needs of each case study.

#### **3.2.4. Identification of all non-experimental variables and methods of control**

- Use the same kiln for every heat development experiment
- Use the same manufacturer of glass rods and if possible the same batch of furnace glass in the control and the experimental work
- Ultra violet light exposure and heat development should be done by the same person for a series of experiments so as to ensure repeatability.
- Exposure to ultraviolet light should be done in the same darkroom for repeatability of a comparative series.

#### **3.2.5. Post-experimental data**

After the various experiments had been completed in the kiln, the resulting data were converted into colour comparison development charts. Details regarding the exposure times under ultraviolet light and time heat development firing programs used were recorded. The data was prepared for presentation in the form of comparative tables showing time, colour and temperature development of the photosensitive glass experiments<sup>17</sup>. Sellers (2001) claims that direct scans produce impressive results in that it delivers images with accurate colour, sharp detail, even in shadows and highlights. These results were possible because the Power Look II has a density range of 3.4 Dmax for fine details, a 1200 x 2400 CCD, and an effective 42-bit output (which allows the capture of more colour information and better colour fidelity than the more conventional 36-bit scanners) using UMAX's patented Bit Enhancement Technology .

#### **3.3.0. Designing the equipment**

Three items of equipment needed to be designed for this research. They were:

- An Ultraviolet light box for the exposure of the photosensitive glass experiments see Figure 10: 3.3.0. Diagrammatic drawing of light box.

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<sup>17</sup> See chapter Six, Case Study Six.

- A miniature furnace for melting soda lime glass and photosensitive glass see Figure 11: 3.3.0. Diagrammatic drawing of Dudley Giberson's ancient-type of furnace and Figure 12: 3.3.0. Diagrammatic drawing of Generation 3 Bead-making furnace by Dudley Giberson.
- A flat-bed kiln for the heat development stage experiments or any other glass kiln available.

The purchase of an ultraviolet light box was considered but when faced with the costs of importing one from PCB Equipment in the United Kingdom or from Olympic Color Rods, Seattle, Washington State, USA a decision was made to design and build one, with expert advice from Mr. W. (Bill) Nichol, Senior Clay & Glass Technical Officer and using the Wood work and Clay & Glass workshop facilities at Curtin University, Bentley, Perth, Western Australia.

### **3.3.1. Designing the ultraviolet light box**

Pre-experimental action plans were designed and drawn up for the construction of an ultraviolet light box that would fit over an electric potter's wheel head. The dimensions for this box were 1 m<sup>2</sup> and were based on being able to place two 600 mm black ultraviolet fluorescent lights diagonally across the roof of the light box. The ultraviolet light box was then made up in the woodwork facility at Curtin University of Technology<sup>18</sup>. The unit was constructed using MDF compressed wood. The interior of the box was painted with two coats of white Watty Solar Guard gloss paint...Solar Guard is an ultraviolet light protective paint and gloss was used for reflective purposes. The instructions received from Gaffer glass on delivery of the rods of photosensitive glass were followed with regard to the optimum placing of the objects to be exposed in the light box. Pencil marks indicating this optimum area were drawn on the inside of the side walls of the light box. A large ceramic pot was measured to this desired optimal height for

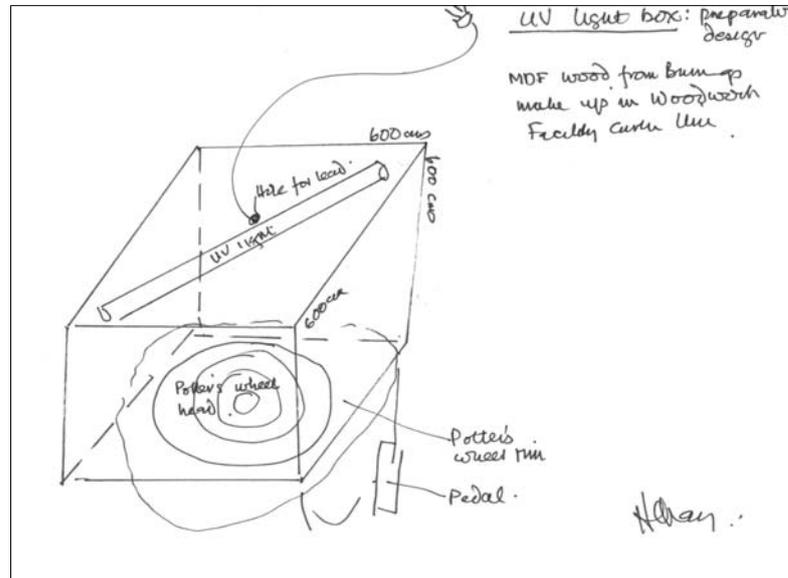
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<sup>18</sup> Olympic Color Rods, of Seattle, Washington offers Photosensitive Glass Products in their catalogue on page 12. The most expensive item, the G-Sunlamp plus 6ft electrical cord for attaching onto the K-FIXTUR-E-20 or the K-FIXTURE-E40 both 2 ft long, comes with the bulbs included. PCB Equipment – UV Exposure Units advertise three steel framed units for exposing photosensitive glass art work. This company is based in the United Kingdom.

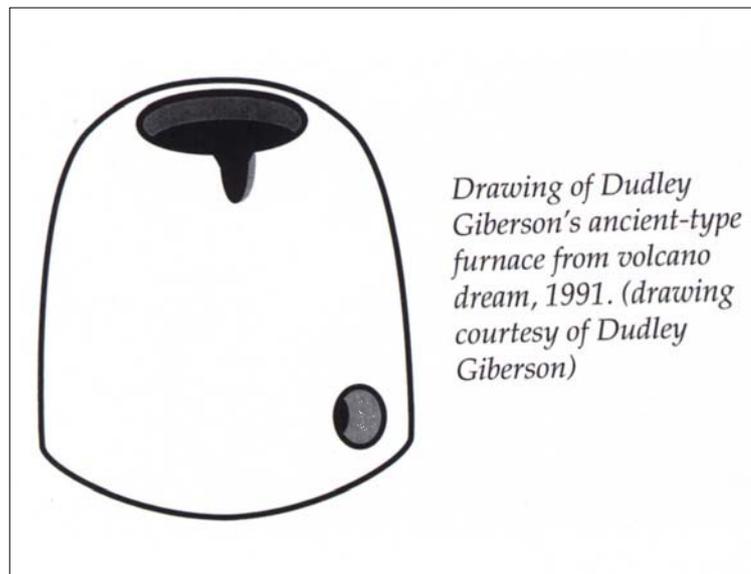
exposure and then placed securely on the wheel head. A wooden bat was then attached to the top of the ceramic piece ready to receive the piece of photosensitive glass to be exposed. This arrangement was only used for exposure of flat pieces of photosensitive glass. When exposing photosensitive Pate de verre chips of glass paper or tin foil cup-cake holders were pinned to the wooden bat then numbered. This was a precaution taken to prevent the set of experiments from flying off the bat during rotation of the wheel head. Tin foil was used to aid reflection from the overhead fluorescent black light tubes onto the glass chips. An alternative bracket for holding a single tube of 600 mm ultraviolet black light was later placed on one of the sides of the box. This was done for the purpose of exposing an object of some volume and height, such as a vase. One of the top fluorescent black light would be removed from the top of the box and placed along the side of the box for the exposure stage.

The design of the miniature furnace used in this project was researched and a suitable prototype from *Glass: An Artist's Medium in the Lampworking Section 4. Lampworking* (Kohler1998, 48) was used. The bead-making furnace illustration by glass artist Dudley Giberson looked simple and achievable. Dudley Giberson was contacted and permission to reproduce his bead making furnace illustration was requested and granted. A few modifications were made in this furnace design, such as a space for a miniature crucible to hold the molten glass and a glory-hole on one side for the experimental flashing of photosensitive glass.

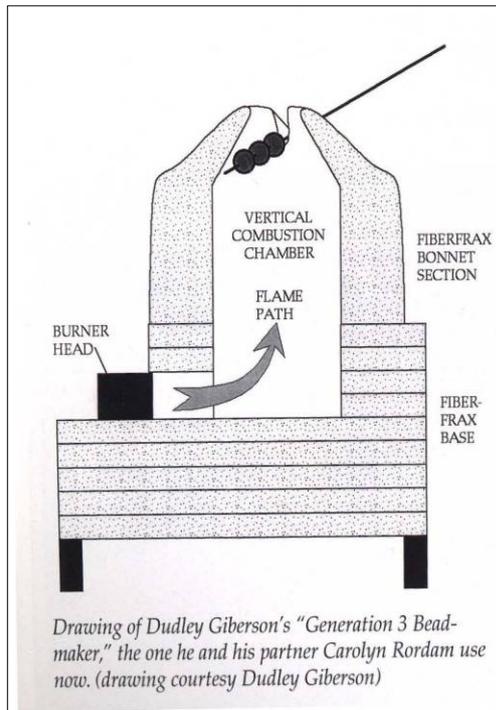
**Figure 10:3.3.0.** Diagrammatic drawing of ultraviolet light box for exposing images onto photosensitive glass.



**Figure 11:3.3.0.** Diagrammatic drawing of Dudley Giberson's ancient-type of furnace.



**Figure 12:3.3.0.** Diagrammatic drawing of Generation 3 Bead-making furnace.



**Figure13(a):** 3.3.0. Designing the equipment  
3.3.1(a) Designing and building the ultraviolet light box



1. Double UV light tube holding frame.



2. UV light tube position under top of box.



3. Height measurement on pottery wheel.



4. UV light proof exterior paint.



5. Measurements inside box.



6. Photographic studio red light.

**Figure 13(b): 3.3.0: Designing the equipment**

*3.3.1(b). Altering the ultraviolet lighting in the light box.*



*7. Studio view of UV light box and red light*



*8. Positioning second UV light tube holder.*



*9. Bill altering UV light tube on side of box*



*10. UV light box with repositioned tubes.*



*11. Interior of light box showing wheelhead*



*12. UV light box with repositioned tubes.*

### **3.3.2a. HEALTH AND SAFETY ISSUES<sup>19</sup>**

#### **The Eye**

The danger to the eye is enhanced by the fact that light can enter from all angles around the eye and not only from the direction that the bead-maker is looking. UV radiation exposure can damage the cornea, the outer protective coating of the eye. Photokeratitis is a painful inflammation of the eye caused by UV radiation-induced lesions on the cornea. Symptoms include a 'sand-like' feeling in the eye that can last for several days. The lens can also be damaged and there is reason for concern because cataracts are the direct result of lens damage. Eye protection was worn at all times when there was UV exposure. Eyeglasses should be ANSI-Z87 rated and provide protection from side exposure via a side lens of 'wrap around' lens. Normal eye protection, prescription glasses, or contact offer little to no protection therefore a closed box fitted around the rotating wheel would be desirable.

#### **3.3.2b. Exposure of the photosensitive glass experiments under ultraviolet light**

Uniformity of the UV illumination inside the light box was considered and the suggested rotating turntable as suggested by Gaffer glass in their operating instructions and a pottery wheel head was substituted. The photographic subtractive exposure method was used. Photosensitive glass contains microscopic particles of metallic compounds such as gold and cerium, so when ultraviolet light passes through a photographic negative onto the glass surface, a latent shadowy

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<sup>19</sup> The main source of UV exposure is the sun. Exposure from the sun is typically limited to the UV-A region, since the earth's atmosphere protects us from the more harmful UV-B and UV-C rays. However, additional precautions should be taken when working in a laboratory because common lab equipment can generate concentrated UV radiation in all three regions. Ultraviolet radiation is found in biological safety cabinets, **light boxes**, and cross linkers in many University laboratories and in some patient care rooms. One of the problems in working with UV radiation is that the symptoms or overexposure are not immediately felt so persons exposed do not realize the hazard until after the damage is done. (JABSOM EHSO-UV Radiation SOP 2009, January).

image is formed within the glass. When the glass is heated, the latent image is converted into a visible image (Gaffer Glass 2002).

### **3.3.2c. Establishing procedures for data collection and analysis**

Procedures for establishing data collection and analysis can be seen in Appendix Ai (b) (Chapter Three).

### **3.3.3a. Technical information regarding the use of the ultraviolet light box**

Exposure of the photosensitive glass to ultraviolet light requires peak UV radiation, and usually requires considerably more exposure time than ordinary photographic material. The wave length of light required (300-350m $\mu$ ) can be supplied by sunlight (as in gum printing and cyanotype printing) but because exposure under sunlight is considered to be too variable, the results cannot be relied upon. Using a commonly available florescent suntan tube gave more consistent results. A Phillips TW40W/09N low pressure mercury vapor florescent tube was suggested. I used two NEC20W fluorescent black light tubes so that I would be able to keep one at the top of the box and one diagonally situated down one of the sides of the box when I needed to expose a three dimensional glass object to ultraviolet light. *“Because the final form of the image may be three dimensional, it will be necessary for the exposure to be carried out with parallel rays which act perpendicularly to the glass surface”* (Croucher 1991, 23). It is advisable that the ultraviolet light is switched off when opening the box after the exposure stage as damage to the human eye can occur if it is exposed to the ultraviolet light without wearing the recommended protective eye glasses. Photosensitive glass contains microscopic particles of metallic compounds such as gold and cerium, so when ultraviolet light passes through a photographic negative onto the glass surface, a latent shadowy image is formed within the glass. When the glass is heated, the latent image is converted into a visible image (Gaffer Glass 2004). The designs of appropriate firing programs were adapted for firing photosensitive glass using *Firing Schedules for Glass: The Kiln Companion* by Graham Stone 1999.

### **3.3.3b. Pre-experimental action**

A check-list was made in working note book for designing and setting up the equipment. Procedure for the pre-experimental action that was taken can be seen in Appendix Ai (b) (Chapter Three).

### **3.3.4 The Miniature Furnace**

When it was discovered through scoping experimentation that photosensitive glass needed to be '*flamed*' before it could be incorporated into the selected traditional glass-making techniques, the concept of building a miniature furnace was justified. The purchase of a miniature furnace was considered. Research for manufacturers of miniature furnaces that were similar to traditional large glass making furnaces was undertaken. There were several miniature furnaces available and I found them to be prohibitively expensive, in addition the furnaces suitable for this research were all manufactured overseas. Internet information on how to build a miniature furnace was interesting but the furnaces appeared to be micro-miniature furnaces for 'one off' experiments. The Flamefast – CRM 700 Tilting Crucible Furnace, designed to work with natural gas, propane or butane suited the needs of this research but was unobtainable because of its high price. In addition to the pricing factor, this tilting furnace was manufactured for melting metal and not glass. My training as a ceramicist led me to consider building a Bead-making furnace. I based the concept for the design of my miniature furnace on an illustration of a small 'Volcanic Dream' Bead-making furnace by Dudley Giberson of Joppa Glassworks, Warner, New Hampshire, United States of America.

#### **3.3.4a. Building my miniature furnace**

With technical assistance in the Clay & Glass workshop, a similar miniature furnace to Dudley Giberson's 'Generation 3 Bead-maker' was built. My miniature furnace was designed to be a bead-making furnace and a crucible furnace for melting photosensitive glass.

The adaptation of 19th century alternative photographic printing techniques to new creative technologies by combining them with photosensitive glass technology of the 1950's, was a way of expanding the boundaries of glass-art and photographic printing technology and could result in the design of a wider range of glass processes. This adaptation of these old technologies to modern creative practice required an innovative and entrepreneurial application of materials research, based on experiments grounded in art and design practice. Any newly developed hybrid technological processes are seen as having characteristics and qualities that have value in their own right rather than being considered as a means to an end, or a way of producing a simulation using computer aided design. (Thirkell and Walters 2007, 232-245). Alternative photographic techniques developed by nineteenth and early twentieth century art and design practitioners have been given a new perspective in terms of their application to photosensitive glass-art and technology (Petrie, 2007, 1). While experimenting with his discovery of photosensitive glass, S.Donald Stookey exposed a photograph onto his photosensitive glass using ultraviolet light and heat development. The result was that the photographic image was permanently imbedded within the glass body.

**Figure 15(a):** 3.3.0. Designing the equipment.

*3.3.2(a) Building the miniature bead-making furnace*



1. Cutting the K26 bricks.



2. Fitting cut K26 bricks into hexagonal shape



3. Fitting bricks onto hexagonal base.



4. Applying mortar to base & bricks.



5. Measuring the flue hole of furnace dome



6. Underside of metal furnace dome.

**Figure 15(b):** 3.3.0. Designing the equipment.

3.3.2(b) Building the miniature bead-making furnace



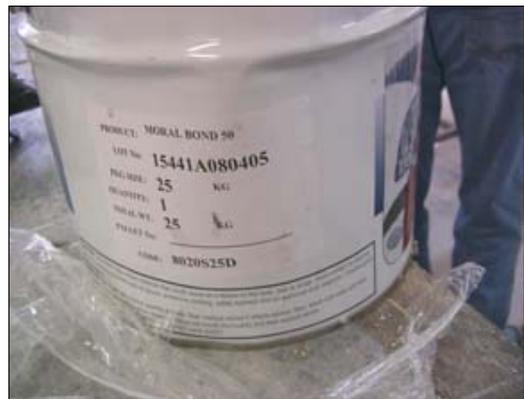
7. Dome lined with fibre.



8. Ceramic furnace buttons.



9. Fitting brick base onto dome.



10. Mortar for furnace bricks.



11. Dome placed on top of base.



12. Insulated base – ready for firing.

### 3.3.4b. The construction process

This miniature furnace was built using refractory<sup>20</sup> E26 bricks cut to fit a hexagonal shaped metal base. The refractory bricks were fitted to the metal base then a wall of bricks<sup>21</sup> was cut and shaped to fit the hexagonal base. Once these bricks were fitted, mortar was applied to the base and sides of the bricks as a refractory cement and sealant. This construction was the '*hot face*' of the furnace. An opening, suitable for the insertion of the gas burner head was made. While the mortar was drying a galvanized iron hexagonal dome to fit on top of the wall was constructed. The 9 mm flue hole for the furnace dome was carefully measured. A set of sixteen ceramic buttons were made<sup>22</sup> and were used to hold the refractory ceramic fibre<sup>23</sup> lining placed on the inside of the dome as light-weight insulation. Following the lining of the dome, the base was fitted to the dome and adjustments were made. A kiln shelf with a small hole was placed over the flue hole of the dome to act as a heat control damper.

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<sup>20</sup> Refractories are materials that will stand high temperatures. A wide variety is available. Almost all of those used for glass furnaces were traditionally based on clay-related and clay bonded materials. Many modern refractories have moved away from this source. In glass making it is essential to use materials which are as free from iron as possible, which will have sufficient mechanical strength and which will resist attack both from hot glass and from any volatiles which may be released (Bray 2001, 197) from the Dictionary of Glass: Materials and Techniques, 2nd edit. (2003).

<sup>21</sup> Sillimanite and mullite refractories are commonly used in glass furnaces. Both Sillimanite and mullite refractories are commonly used for the walls of tank furnaces where there is glass contact (Bray 2001, 198). Molten glass attacks refractories largely because of the corrosive action of the alkali. The temperature and the porosity of the refractories are also important in this context.

<sup>22</sup> From Courtland's Cream Raku clay. The ceramic buttons were fired in an electric kiln to 1200 degrees Celsius for the first firing then again to 1280 degrees Celsius for the second firing

<sup>23</sup> Ceramic fibre is manufactured from various alumino-silicate materials and made into a wide range of forms for use as lightweight, high temperature insulations. It is available in a number of grades, shapes and qualities to suit the particular specifications required. Especially high temperature material is made which incorporates zirconium silicate and is used increasingly in burner blocks and forehearth applications. Ceramic fibre is an irritant material which, in the EC has been found to be carcinogenic in animal tests. As a result, whilst there is no ban on its use there are specific recommendations concerning the nature and the amount of exposure to ceramic fibres (Bray 2001, 73, 142)

### 3.3.3c. Testing the miniature furnace

The first test used a hand-held propane gas nozzle burner<sup>24</sup> attached to a propane gas cylinder. The aim of this scoping test was to find out if the miniature furnace would be able to reach a temperature between 884 degrees Celsius and 984 degrees Celsius. Three Standard Orton pyrometric cones<sup>25</sup> were used to test the temperature of the crucible. They were placed on the refractory shelf made to hold the crucible. This test is the traditional ceramic method used to test kiln temperatures rather than using a pyrometer. Standard pyrometric cones measure work done by heat in the kiln whereas a pyrometer measures temperatures of any given time. This technical information came from a personal communication with Adjunct Professor John Teschendorff. Standard cones are used three at a time pushed into a wad of raku clay. The centre cone is the desired temperature, the cone before it is the warning cone and the remaining cone is the guard cone. When the third (guard) cone bends its tip over this indicates that the temperature is too high. The numbers of the three cones used to 'test' the first firing of the miniature furnace were numbers 019=685 degrees Celsius, the (warning) cone, 010=894 degrees Celsius the desired temperature and 08=955 degrees Celsius the guard cone ( Kohler 1998, 209). As each cone tipped the length of time it took was noted and recorded from the start of firing the furnace to the first cone tipping. In general it took about 2 hours and 40 minutes to get the third or guard cone to tip. Most soft glasses (COE95 and above) become molten at cone 010/894 degrees Celsius and Soft glass (COE95 and below) becomes molten at cone 09 - 924 degrees Celsius (Kohler 1998, 209).

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<sup>24</sup> A number 3941 Sievert gas burner nozzle suitable for foundry work was selected with steel tip of 15 and a flame length of 14 centimetres. The kPa recommended working pressure was 200-400. The gas consumption rate was gh at 200 kPa and the heating effect in watts was 3,350. (personal communication from salesperson from Kleenheat gas, Myaree, Perth.WA).

<sup>25</sup> Three-sided pyramidal forms of clay based material designed and made to be placed in kilns to measure heat work. With heat they soften and bend over. They are used mainly by potters and are rarely used by studio glass-makers (Bray 2001, 82).

### **3.3.3d. The second test**

Two glass beads using the traditional mandrel were then made using the heat from the flue. Following the bead-making an attempt to melt large chips of soda lime glass in a gold assay refractory beaker was made. The assay beaker was then removed from the centre of the furnace after the dome had been lifted off and an attempt to pour the molten glass in a refractory gold assay beaker was made.

### **3.3.3e. Making refractory crucibles to fit the miniature furnace.**

Despite the fact that small crucibles were readily available from suppliers of refractories, the decision was made to construct and produce them and then fire them in the Clay & Glass Workshop. By making my own crucibles I was able to exactly fit the dimensions of the crucible chamber of my miniature furnace.

### **3.3.3f. Further alterations and additions**

I designed and constructed a large ceramic dome-jacket with a flue-hole then bisque-fired it in an electric ceramic kiln. This jacket was used to cover and insulate the metal dome while the furnace was being fired. A separate round flat ceramic kiln shelf was used to adjust the heat outflow from the flue. The jacket was removed when access to the furnace glory-hole was needed. The first ceramic jacket had a lid on the side where the glory-hole was situated but this design proved to be unsuitable because the jacket cracked as soon as any metal object touched it. I then designed and constructed a second much larger and higher ceramic jacket to fit over the metal dome. This second higher jacket turned out to be a suitable means of aiding the rate of temperature elevation of the glass being melted in the crucible. Several long punties (pontils) and several miniature blow pipes<sup>26</sup> were made-up from stainless steel pipes. The punties and blow pipes were heated at the port where the burner was situated.

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<sup>26</sup> I cut and polished my miniature stainless steel punties and blowing pipes (under expert supervision of the incumbent technician) by using the facilities of the Metal Workshop at the Curtin School of Art.

**Figure 15(c): 3.3.0. Designing the equipment.**

*3.3.2(c) Trial testing the miniature bead-making furnace*



*13. Testing the dome for keeping heat in.*



*14. Making the first bead.*



*15. Hot crucible in base.*



*16. Tongs holding hot crucible.*



*17. First pour from hot crucible.*



*18. Tipping out contents of hot crucible.*

**Figure 15(d): 3.3.0. Designing the equipment.**

*3.3.2(d) Trial testing the miniature bead-making furnace*



19. Insulation around base.



20. Testing dome on insulated base.



21. Making a bead in insulated furnace.



22. First two beads made.



23. Gas burner in situ.



24. Insulated furnace set up on table.

**Figure 15(e):** 3.3.0. Designing the equipment.

3.3.2(e) *Altering the miniature bead-making furnace*



25. *Template marked for further insulation.*



26. *Clay used for outer ceramic jacket.*



27. *Firing of outer ceramic jacket in kiln.*



28. *Painting kiln wash inside ceramic jacket.*



29. *Painting kiln wash over fibre and mesh.*



30. *Blocking off flame port from insulation.*

**Figure 15(f): 3.3.0. Designing the equipment.**

*3.3.2(f) Altering the miniature bead-making furnace*



31. Ceramic jacket before insulation.



32. Perlite and vermiculite insulation in situ.



33. Dome on top of newly insulated jacket.



34. Glory-hole design.



35. Fitting aluminium ring to glory-hole.



36. Glory-hole ring on side of dome in situ.

### **3.3.3g. Summary**

The provision of an incorporated glory hole made a great difference to the uses that the miniature furnace could be put to. Not only could the furnace be used as a bead-making apparatus it was able to be used for making molten glass for pouring into moulds, the molten glass could be accessed by both punty and blowing iron for the manufacture of stringers and canes in miniature form. Several early attempts were made to blow the molten glass using the miniature stainless steel blowing irons and some attempts proved to be successful. Most importantly, photosensitive glass could be '*flashed*' in the glory hole until it was ready for use in a variety of experiments.

**Figure 15(g): 3.3.0. Designing the equipment.**

*3.3.2(g) Altering the miniature bead-making furnace*



37. Fresh clay bowl for dome jacket.



38. Extra crucible acting as bung in dome.



39. Ceramic dome with glory hole



40. Ceramic jacket with lid for glory-hole.



41. Heating up small blowing pipes.



42. Re-insulated dome of furnace.

### **3.3.4. The flat-bed kiln**

Kilns for glass working are basically the same as those used for firing ceramics except that as they are most unlikely to be used for temperatures above 1000 degrees Celsius. Modern electric kilns suitable for casting, fusing, slumping, and annealing are often made from ceramic fibreboards, which are grooved as necessary to take the elements. Some adjustments to the firing programme may be required as solid refractories tend to hold a lot of heat and so ensure slow cooling, particularly at the bottom of the range, ceramic fibre holds almost no heat. As a result, if the kiln is left to cool off naturally, the fall can be far too rapid for thick glass to cool safely. Fully programmable controllers are becoming commonplace in glass studio (Sale 2003). This means that the possibility of a too rapid temperature reduction can be avoided by automatic control (Bray 2001, 150).

### **3.3.5. Testing the flat-bed kiln**

Standard Orton pyrometric cones<sup>27</sup> were used by the builder of the flat-bed kiln, Mr. Bill Nichol, Senior Technical Officer, Department of Clay & Glass, School of Art, Curtin University of Technology, to measure the temperature that I was planning to fire the glass experiments to in my flat-bed kiln, to see if there was an even heat distribution across and along the refractory shelf that made up the base. The top temperature tested for was (cone 07) 984 degrees, The cones were placed on the refractory shelf, groups of three cones down the left-hand side back middle and front, three in the middle of the shelf, back middle and front and three on the right-hand side in the same configuration. To calibrate the desired temperatures a Harco digital pyrometer was used. Standard pyrometric cones measure work done by heat in the kiln whereas a pyrometer measures temperatures of any given time.

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<sup>27</sup> Three-sided pyramidal forms of clay based material designed and made to be placed in kilns to measure heat work. With heat they soften and bend over. They are used mainly by potters and are rarely used by studio glass-makers (Bray 2001, 82).

Technical details regarding the building of the Flat-bed kiln can be seen in Appendix Ai (b) (Chapter Three).

**Figure 16:** 3.3.0. Designing the equipment

3.3.4. Custom-made flat-bed kiln



*My flat-bed/Annealing kiln used for bead-making, annealing and other experiments.*

<b><i>Exterior measurements</i></b>	<b><i>Electricity volts: 240</i></b>
<i>Width: 86 cms Length: 68 cms Depth(Height: 38 cms.</i>	<b><i>Phase: 1 Amps: 15</i></b>
<b><i>Interior measurements</i></b>	<b><i>KW Rating: 3.6</i></b>
<i>Witdth: 72 cms Length: 52 cms Depth(Height: 32 cms)</i>	<b><i>Maximum temperature: 1000 degrees Celsius</i></b>

Case Studies were assigned to the selected traditional techniques thought to be suitable for the incorporation of photosensitive glass. Several Case Studies had sub-categories. These sub-categories were subjected to scoping experiments and if there was a possibility of incorporation into the traditional technique, further experimentation was carried out. The relevant literature on the subject of photosensitive glass was reviewed, before proceeding to design the experiments in order to achieve this aim.

### **3.4.0. Summary**

Experiments with the materials, with the view of looking at the aesthetic and technical potential of the materials that could lead to the creation of new innovative industries as well as leading to a new audience and inspire fresh new work with potential economic outcomes were undertaken (Florida: Creative Clusters 2001-2000). The significance of designing and building the ultraviolet light box, the miniature furnace and the flat-bed kiln were important activities as they were the three pieces of equipment vital for carrying out the scoping experiments and the successful experiments. This undertaking assisted me in understanding the technical side needed for my research. Participant observation was an important aspect of this research for it enabled me to physically assess the actual stage where the photo sensitive glass would be applied in the selected techniques. Collaboration with my glass-making colleagues and the glass artists that I encountered while acting as a participant observer played a significant role in the research. The wider context for this work is its future contribution to a contemporary creative economy through working in a 'Creative Cluster'<sup>28</sup>. Materials research has a place in this type of creative design practice. It has the potential to contribute to new innovative industries, lead to products for new audiences as well as current audiences, and inspire new work with potentially new

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<sup>28</sup> Florida Richard 2003-2005. Florida Creative Cluster <http://www.onenortheast.co.uk>.

economic outcomes. In addition, this materials research should foster a symbiotic relationship between the arts, industry and the sciences.

In Chapter Four, I discuss my plan of work which includes my practice-led research, my selected case studies, my case study methodology, collaborations, my role as a participant observer and volunteer assistant. I discuss the designing of my case studies using a case study protocol.

## **CHAPTER FOUR - PLAN OF WORK**

### **4.0.0. INTRODUCTION**

This chapter describes how I went about planning, building and conducting my research on a case study methodology. My plan of work included:

- My selected case studies.
- My role as a participant observer and volunteer assistant in a hot glass studio.
- The collaborations that I entered into.
- Problem solving.
- Designing my research Case Studies.
- Participant observation research documentation.
- Practice led-research.
- The designing the case study Protocol.

The purpose of my case studies was to extend the traditional glass making techniques being used by glass artists and glass designers by attempting to incorporate photosensitive glass into some traditional glass making techniques. The final outcome of these scoping experiments and their potential is discussed in Chapters Five and Six.

### **4.1.0. PLAN OF WORK**

My plan of work was based on a research journey of exploration and having mapped the terrain through a contextual literature review I was able to locate the position where I could start my research (Gray and Mullins 2004, 14, 68) which was at the point where I selected the traditional glass-making techniques that I considered suitable for photosensitive glass incorporation. My research was now focused on discovering, through extensive systematic experimentation how photosensitive glass could be incorporated into selected traditional glass making

techniques. In order to achieve this goal, one of the strategies I employed was to work as a participant observer at the Hyaline Hot glass studio for a full day once a week for the years 2003 to 2008, so as to become familiar with the working practices of the many glass-artists who worked there. Another strategy was to assist the gaffer and other artists whenever I could or when I was needed. I did not make glass-art work, but used the knowledge I gained through observation and enquiry to assist me in estimating the traditional glass making techniques that would be suitable for photosensitive glass incorporation. Many hours were spent discussing the various aspects of my research with my colleagues in the team and visiting glass designers/blowers<sup>29</sup>.

My role in the hot glass studio enabled me to attend workshops at the hot glass studio given by local artists as well as workshops from international artists and artists from the Eastern States of Australia was the third strategy I employed to broaden my exposure to art glass practice and achieve my goal. An additional strategy that I used was through collaborations with some of the glass artists that I met and assisted. Collaborations were proposed and some were commenced. Gray and Malins (2004, 2) argue that learning occurs within a social context and it was by volunteering as an assistant/participant observer at the Hyaline Hot Glass Studio I was able to engage in the active exploration of the research process that drove my research. By assisting in the hot glass studio with a number of art-glass making artists, I was able to gain a greater inside knowledge of the traditional procedures and techniques they used, some of which often differed slightly. It was because of the slight differences of technique that an artist/colleague had developed in carrying out a traditional technique, I was able to make choices regarding the technical methods I could use to incorporate photosensitive glass into the techniques that I was researching. Courmans (2003) points out that the research direction of an artist designer is a transparent process in which conscious steps are taken, in which knowledge is used and or searched for. It is important

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<sup>29</sup> The wish to remain anonymous was requested by various visiting glass artists.

that the artist/designer have sufficient knowledge about the art and design processes being researched to justify the choices that are made.

#### **4.2.0. Participant observation research documentation**

As a participant observation researcher, I was able to document many traditional art-glass making techniques by using photographic equipment. Documentation using video-photography and digital photography for capturing the traditional techniques practiced in the studio played an important part in recording what I observed. Photography was used to illustrate the study of the interplay between the various members of the glass team and designers as well as the different ways they approached the traditional art-glass making techniques. The different views and slightly different ways of approaching the art-glass making processes enabled me to triangulate the practices that I had observed, with a view to corroborating my selection of suitable techniques. By using photography, I was able to reflect on what I had observed each day and then to apply this gained knowledge to designing the scoping experiments that I thought would be the key to incorporating the photosensitive glass into the traditional technique. I was then in a position to identify and select a number of traditional art-glass making techniques for my research. Each of these techniques was allocated a potential case study number for experimentation and documentation purposes. Some of the selected traditional techniques were subjected to many scoping experiments because each glass-maker had developed a different and novel approach to that technique. My aim was to make the creative research process visually comprehensible by capturing each step of the art-glass making techniques photographically or video-graphically before applying scoping experiments using photosensitive glass. By documenting each stage of the scoping experiments I was able to re-visit that stage many times, reflecting, evaluating and analysing the outcomes.

### **4.3.0. Practice-led research**

My practice-led research was informed by observing the many different ways that some of the selected traditional art-glass making techniques that were being practiced in the hot glass studio. These observations enabled me to decide that experimentation would be the chosen research methodology. Scoping experimentation was used to expose the problems of how to incorporate photosensitive glass into the selected traditional techniques and create alternative pathways for using the traditional art-glass making techniques. The experimental scoping processes that I used were based on the scientific method and the 19<sup>th</sup> century alternative photographic printing processes such as Gum Di-chromate-printing<sup>30</sup> and Cyanotype printing (Tarlus 2003). These alternative photographic printing processes were adapted using an Umax Power lock II Scanner and the computer program Photoshop 6. Exposure of the manipulated images onto the photosensitive glass experiments were made under safe light conditions in an ultraviolet light box. Photosensitive glass contains minute chemicals that can be compared with the hand-applied chemicals onto rag-based paper that was used to develop images by the ultraviolet rays of the sun. Photosensitive glass requires timed exposure under controlled ultraviolet light in order to develop a latent image. By using a red photographic darkroom light the exposure to ultraviolet light eliminates any untimed exposure variable.

#### **4.3.1. Problem solving**

Often I would take the process apart and reassemble it in a different way when I encountered a problem. I would then repeat that particular experimental stage before continuing. I labeled this problem stage the ‘*key*’ stage because it was pivotal to the success of the scoping experiment. When a scoping experiment had a positive outcome and showed potential it was analysed and then repeated as a ‘*blue print*’ for the relevant case study experiment. It was then documented in

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<sup>30</sup> Early photographic processes. Gum Dichromate Process: popular 1894-1920s.

Chapter Six. When a scoping experiment went awry, I would remain flexible, pull the experiment apart and attempt a slightly different method for the second or third scoping experiment. I regarded these alternative scoping experiments as future possibilities. If there was a positive outcome from the second or third attempts, the experiment would be analyzed and compared with the failed scoping experiments and documented before further testing as described in Chapter Five. Gray & Malins (2004, 31) argue that research in art and design involves multiple methods, primarily visual, originating from practice or adapted for practice-led research from other research paradigms.

#### **4.4.0. Case Studies**

I decided to use case studies to form the structure of my plan of work because the case study allows the researcher to concentrate on specific instances in an attempt to identify interactive processes. My aim in using the case study method was to provide a way of looking at all aspects of the situation. This argument is supported by Lubbe (2003) when he described case study methodology as being an umbrella term for a group of research methods that have in common the decision to focus an inquiry around a specific instance or event.

##### **4.4.1. Research methodology in relation to the nature of the research problem**

The case study research methodology suited the nature of my research problem in the areas of art-glass design, art, science and the technological field of alternative photographic printing as well as in combination with other research methods. *“The choice of research methodology is dependent upon the nature of the research problem”* (Khairul Baharein Mohd Noor, 2008). Zonabend (1992, 49-60) cited by Tellis (1997) argues that case study research is done by giving special attention to completeness in observation, reconstruction, and analysis of the case under study.<sup>31</sup>

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<sup>31</sup> Winston Tellis (1997) cites (Feagin, Orum & Sjoberg) who state that case study research is an ideal methodology when a holistic, in-depth investigation is needed.

Seven case studies were identified as potential areas for development but not all were expected to be followed through to completion as the scoping experiments would identify whether it was possible to incorporate photosensitive glass into a particular traditional art-glass making technique. The scoping experiments for each case study in Chapter Five act as a structural base or support for the final experimentation in Chapter Six.

In this research, the case studies thought to have most potential of the selected seven traditional art-glass making techniques were:

- Case Study One: Pulling or drawing out processes
- Case Study Two: Recycling processes
- Case Study Three: Bead-making/Flame-working processes
- Case Study Four: Kiln forming/ kiln casting processes
- Case Study Five: Furnace casting processes
- Case Study Six: Free blowing processes
- Case Study Seven: Acid etching/acid embossing processes (hazardous).

As the practical work progressed, there was refinement and selection. During experimentation, new techniques and processes had to be invented through necessity to solve problems that occurred, so as to maximize the potential of photosensitive glass.

Bromley (1986) defines a case study as a systematic inquiry which aims to describe and explain the phenomenon of interest into an event or a set of related events. The case study method complies with the basic tenets of the scientific method as it involves classification, observation and descriptions of sequences and consequences when using a well-defined protocol (Lubbe 2003.) In her paper Sue Soy (1997) cites researcher Robert K Yin (1984, 23) as defining the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident and in which multiple sources of

evidence are used. This research is materials based, experimental and practice-led. It is grounded in art and design practice and is appropriate for the methodological case study approach as it prioritizes gathering data from which I could develop grounded theory. Strauss and Glazer (1967) developed the concept of 'grounded theory'. This, along with some well regarded studies accelerated the renewed use of case study methodology (Tellis 1997)<sup>32</sup>. The case study research method was used to develop a strategy for the technique for answering the 'who', 'why' and 'how' questions that needed to be answered.

Case study protocol consists of procedures that should be regarded as survey instruments. The protocol is a detailed master plan for the research. It is a document in which full details of the case study research design, including details of the questions to be asked, details of all types of evidence required, as well as the structure of the final research, are specified. The format for the case study protocol and report outline should be in the narrative. The typical protocol should contain an overview of the case study project such as objective, issues, and topics being investigated Yin (1994, 64). The experimental approach was used in the case study method of my research as case studies lend themselves to generating and testing by hypotheses (Flyvberg Bent 2006, 219-245). One of the survey instruments used to identify potential case studies for photosensitive glass incorporation was my prior experience with the technical processes that were used in the many areas of glass art that I had been exposed to as an undergraduate student. Another survey instrument that I used to identify the potential of a glass making technique was my experience as a participant observer/assistant in the glass blowing studio. Attending conferences and workshops given by international visiting glass artists can be included as important survey instruments that I used for my research.

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<sup>32</sup> *"The history of case study research is marked by periods of intense use and periods of disuse. The earliest use of this form of research can be traced to Europe, predominately to France. The methodology in the United States was most closely associated with the University of Chicago, Department of Sociology. From the early 1900's until 1935, The Chicago School was pre-eminent in the field and the source of a great deal of the literature"* (Tellis 1997).

#### **4.4.2. Identification of sources**

Tellis (1997) cites Stake (1995) and Yin (1994) as having identified at least six sources of evidence in case studies<sup>33</sup>, however, Yin (1994) argues that it is important to keep in mind that not all sources are relevant for all case studies. Of the six sources of evidence identified by Stake (1995) and Yin (1994), were the documents that served to corroborate evidence in the interest of triangulation of evidence. The documents that I used to corroborate evidence for my research were from the video-graphic tapes and photographs of traditional techniques being executed in the hot glass studio and the workshops that I attended. Archival records on traditional techniques were obtained from the literature search which included online sources. Interviews with visiting glass artists were informal. The request that notes of the conversation would not be taken while the artists were being interviewed was adhered to as they wished to remain anonymous. Collaborations that I had entered into were an important source of identification of how the photosensitive glass was being incorporated in the technique being used by the artist in question. Direct observation of a particular artist demonstrating a glass making technique took place regularly. The physical artifacts of our experiments were the physical evidence of the research results and these were collected as data.

Some specific types of case studies such as exploratory, explanatory and descriptive have been identified as sources of evidence. My research falls into the explanatory category as my investigations were mainly causal (Yin 1994). Case study research is not sampling research; that is a fact asserted by all the major researchers in the field, including Yin, Stake, Feagin et al (1991). Selecting case studies must be done so as to maximize what can be learned in the period of time available (Tellis 1997). My research was conducted from 2003 to 2008.

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<sup>33</sup> The six sources identified by Yin (1994) and Stake (1995) were documentation, archival record, interview, direct observation, participant observation and physical artifacts.

#### **4.4.3. Triangulation research strategy**

Snow and Anderson (cited in Feagin, Orum and Sjoberg 1991) argue that case study research is known as a triangulated research strategy. Triangulation can occur with data, investigators, theories and even methodologies. Triangulation arises from the ethical need to confirm the validity of the processes (Tellis 1997). Yin (1984) believes that in case studies, this could be done by using multiple data sources. Tellis (1997) cites Denzin (1984) as having identified four types of triangulation.

1. Data source triangulation, when the researcher looks for the data to remain the same in different contexts.
2. Investigator triangulation, when several investigators examine the same phenomenon.
3. Theory triangulation, when investigators with different view points interpret the same results.
4. Methodological triangulation when one approach is followed by another to increase confidence in the interpretation.

My research type of triangulation was methodological triangulation when I designed the comparative colour coded interpretive analytical results of the open-face Pate de Verre triaxials in Case Study Four, Chapter Six.

In conducting my research I gained some additional knowledge in the disciplines that are on the periphery of my research interests<sup>34</sup>. Researchers have used the case study research method for many years across a variety of disciplines. Sue Soy (Spring 1997) supports the argument that case study research strengths lie in excelling at bringing a researcher to an understanding of complex issues and can extend experience or add strength to what is already known through previous research. Yin (1994) argues that because the case study follows the logic of the experiment rather than logic of the survey, it is not necessary to repeat a case.

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<sup>34</sup> My research is situated in a space between the disciplines of art-glass, design, art, science and the technology of alternative photographic printing processes.

#### **4.5.0. Designing my research Case Studies**

The first of the following steps for organizing and conducting the research successfully as proposed by Stake (1995) and Yin (1994) that were used in designing my case studies, was to determine and define the research questions relevant to each case study. The second step was to select the cases. The third step was to determine data gathering and analysis techniques. The fourth step was to prepare to collect the data generated by the scoping experiments. The fifth step was to photograph the data before evaluating the data. The sixth step was to report the findings.

Each case study was based on the many scoping experiments that I had made using the selected traditional techniques<sup>35</sup>. I then designed further experiments based on these successful scoping experimental outcomes to support my belief that photosensitive glass could be incorporated into one of these traditional glass making techniques. My purpose in doing this research was to add another dimension to the selected techniques.

##### **4.5.1. Designing the case study protocol**

I followed the advice of Yin (1994, 64) when developing and designing the detailed master plan draft of the protocol document for my case study research. My overview stated the general topic of my research inquiry and an overview of each of the seven case studies was made. My protocol included general rules and procedures about how the research would be conducted, detailed questions to be asked, project objectives, issues and the structure and the presentation of the written format for each case study report and was a useful way to communicate the research information with the reader. The outline and the format for the report was defined and specified. Data sources and data collection and presentation issues were determined. The questions relating to data and their collection,

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<sup>35</sup> The experimental approach is used in the case study method of research (Yin 1994, 64).

Presentation, analysis and interpretation were an important consideration in planning my protocol outline. During the early stages of the scoping experiments a journal form of a reporting format was kept. This format helped me refer to scoping experiments that I had undertaken and may have omitted to report important small details about the steps that I had taken while doing them. My draft of the protocol was initially in point form so as to maintain clarity but was then rewritten to communicate as the basis for narrative in Chapter Five. The discipline of having written a draft protocol outline for general case study application was important for the overall progress and reliability of my research in that it helped focus on the main issues and goals, especially when problems arose during the development stages of the scoping experiments.

**Figure 17:** Table 2.0.0.

4.5.1. Designing the case study protocol.

*This protocol document is the detailed master-plan that guided my research.*

**General rules and procedures about how the research would be conducted.**

1. Place the seven selected techniques (case studies) in order of difficulty.
2. Set out case studies in table form.
3. Divide the case study into sub-categories or units so that they become units of analysis.
4. Define each sub-category.
5. Place each sub-category in its historical context.
6. List modern glass artists using the sub-category's technique.
7. List how and why questions giving reasons why I thought that a particular technique was suitable for the incorporation of photosensitive glass.
8. List propositions derived from the how and why questions (helpful in focusing the case study's goals. Note that all case studies need to have propositions. An explanatory case study, rather than having propositions, would have to state a purpose or criteria on which the success will be judged (Yin, 1994, 20).

**1. The general overview of my research project inquiry into case study.**

- The stated purpose of the case study
- Definition of the case study.

**2. An overview of the sub-category...for case study No: ...**

<p><b>3. My research question (and specific hypothesis) that was applied to each sub-category of the case study.</b></p> <ul style="list-style-type: none"> <li>• Research question</li> <li>• Questions asked – methods used</li> <li>• Clarify the questions and <ul style="list-style-type: none"> <li>• <i>Apply the questions to the units of analysis</i></li> <li>• <i>Link data from the units of analysis to the propositions and</i></li> <li>• <i>Focus on assertions.</i></li> </ul> </li> <li>• My solution to the research problem.</li> <li>• Hypothesis applicable to this sub-category.</li> <li>• Issues</li> <li>• Describe the focus of each sub-category</li> <li>• Process (standard application) and technical skills required.</li> <li>• Identification of a range of experimental issues (what they were).</li> <li>• The experiments.</li> </ul>
<p><b>5. Case study project aims</b></p>
<p><b>6. Detailed questions to be asked by myself, the investigator:</b></p> <ul style="list-style-type: none"> <li>• Prompts concerning the information that has to be gathered by the investigator.</li> <li>• List of sources of evidence that cover observations by the investigator.</li> <li>• Classification.</li> <li>• Observation.</li> <li>• Description of sequences and consequences (Lubbe 2003).</li> </ul>
<p><b>7. Issues:</b></p> <ul style="list-style-type: none"> <li>• Physical Issues</li> <li>• Theoretical Issues</li> </ul>
<p><b>8. Selecting my experimental variables:</b></p> <ul style="list-style-type: none"> <li>• My independent and dependent variables.</li> <li>• How I measured my independent variables and my dependent variables. (Describe exactly what I did).</li> </ul>
<p><b>9. My methods and procedures for collecting data for the case studies.</b></p> <ol style="list-style-type: none"> <li>1. Questions relating to the data and their collection: <ul style="list-style-type: none"> <li>• Data sources</li> <li>• Data collection</li> <li>• Data presentation issues</li> </ul> </li> </ol>
<p><b>10. Analysis of the data.</b></p> <ul style="list-style-type: none"> <li>• <i>Check the data and re-read the results interpretation.</i></li> <li>• <i>Analyse the development of the case study from the experimental evidence.</i></li> <li>• <i>List strengths and weaknesses then identify the problems.</i></li> <li>• <i>Evaluate the options of possible solutions to the problems.</i></li> <li>• <i>Recommend any possible solutions.</i></li> </ul> <p style="text-align: center;"><b>2. Interpretation analysis of my collected data</b></p> <ul style="list-style-type: none"> <li>• <i>By comparing exposure times and</i></li> <li>• <i>By comparing heat development times.</i></li> <li>• <i>Length of time in electric kiln</i></li> <li>• <i>Link the data to the proposition (if there is one)</i></li> </ul> <p style="text-align: center;"><b>3. Criteria for the interpretation of the results</b></p> <ul style="list-style-type: none"> <li>• What the criteria are.</li> </ul>

- *The criteria for interpreting the findings are the results that are linked to the study's propositions claims Seok Won Lee (2003, 1).*

**4. What the KEY issues for this sub-category were.**

#### **4.5.2. Developing and reviewing the protocol**

Because the protocol is a primary tactic in increasing the reliability of the case study procedure at the centre of the protocol is a set of questions reflecting the inquiry that will review and develop the protocol. In order to show 'how' and 'why' in my explanatory type of case studies the following five important components suggested by Yin (1994, 20) was defined during the case study design process: A case study's questions need to be clarified very precisely and can be developed by applying them to units of analysis. The units of analysis are the logic linking of data to the propositions and they focus on assertions that should be examined to answer a case study question within the scope of the study. The case study's propositions are derived from the case study questions. The criteria for interpreting the findings are the results that are linked to the study propositions as evidence through the criteria for interpreting findings Seok-Won Lee (2003,1). Lubbe (2003) argues that certain characteristics that distinguish this set of questions from those used in a survey are the protocol questions that are set for the investigator and not the respondent.

The questions are there as reminders or prompts to the investigator concerning the information that has to be gathered. It is important to remember that a particular protocol is designed for data collection from a single case study and is not intended to cover the entire project. There are some characteristics that distinguish such a set of questions from those used in a survey. Second, each question should be accompanied by a list of sources of evidence that cover observations.

Therefore, in multi-case situations a number of protocols will be required. Using a well defined protocol, the case study method complies with the basic tenets of the

scientific method as it involves classification, observation and descriptions of sequences and consequences.

#### **4.5.3. Case Study Report Guidelines**

Yin's recommendation the report is planned at the start of the case study because case studies do not have a widely accepted reporting format. This recommendation was followed. Yin (1994) also highlighted the importance of the questions and the corresponding research questions before the research is conducted and argued that the reader must be able to discern both the fundamental conceptualization of the case and be able to identify questions or issues under investigation that are derived from it. One of the key factors is the experience of the investigator. Data collection, research questions and the units of analysis cannot always be placed into a fixed mould as in experimental research (Yin 1994). All researchers must reveal the steps they followed so that others can determine the merits of the completed work. A guide for compiling the case study reports forces the investigator to think about the audience for which the case study is intended early in the process of the research. Bacher (2000) argues that there is one fundamental requirement placed on a researcher when reporting case studies, that is, the onus on the researcher is to conduct the case study in such a way that the result can be replicated and communicated to the reader without bias. When a case study report is examined a clear statement of the conceptual underpinning of the case should be seen to appear early in the report. The conceptual issue should be able to be translated into a researchable question or issues, or into a series of questions or issues (Bacher 2003, 4).

#### **4.5.4. Evidence of collection and interpretation**

Evidence collection was applied in a systematic manner. The evidence was the results of the experiments. These results are the data which were collected directly from the flat-bed kiln once the experiments had cooled sufficiently for the data to be handled. The data were scrutinized visually, after which the data were placed onto a photographic light table for a second viewing and a preliminary

interpretation. For a final viewing the data were digitally scanned using an Umax Power Look II scanner attached to a computer. Once the data had been saved on the computer they were then enlarged for interpretation. Interpretation of each case study's data is discussed in Chapter Six.

#### **4.5.5. Theoretical investigation**

For a theoretical understanding of the identified areas with potential, all the selected seven case studies needed to be covered initially. By comparing different case study experimental scoping results, areas for my research were identified for further exploration and experimentation. These identified areas formed a structure for reflecting upon and reporting on innovative studio practice. These results are reported on in each case study in Chapter Six.

#### **4.5.6. Research strategy**

My case studies investigated the phenomenon presented by photosensitive glass technology. I relied upon evidence sourced from the manufacturers of photosensitive glass, the artistic literature and the scientific research literature on how photosensitive glass has been used and is being used to the present day. My methods involved in-depth sequential systemic examinations of experiments of how photosensitive glass could be incorporated into some traditional glass-making techniques. Data collecting, analysis of data results, and the reporting of the results are part of the case study. This approach has helped me to understand why and how photosensitive glass behaves in each selected case study. Numerous scoping experiments done for each case study eliminated previously assumed beliefs. The scoping results indicated what might become important to look at in the actual case studies are discussed in Chapter Five.

#### **4.6.0. Case Study analysis**

Yin (1994) suggested that every investigation has a general analytic strategy, so as to guide the decision regarding what will be analysed and for what reason. He

produced three strategies for general use. First, the theoretical proposition of the study and then to analyse the evidence based on those propositions. The second strategy was to develop a case description, which would be a framework for organizing the case study. Pattern-matching was the third strategy that he suggested. If it were an explanatory one, the patterns may be related the dependent or independent variables and the study are enhanced<sup>36</sup>. Because my case studies were explanatory they did not have propositions, instead they had a stated purpose or criteria on which their success can be judged (Yin 1994, 20). I used exposure times and development times as an experimental techniques in my case study analysis. My case studies and their results were based on the use of dependent and independent variables and the colour results that were produced. Various colour combinations appeared according to certain ultraviolet light exposure times in combination with timed heat development. These colour results can be regarded as a form of '*pattern matching*' when they are compared in all the case studies because of their predictability. Campbell (1975, 178-185) argues that it is possible that a single dependent or independent variable could make analysis simpler than pattern-matching.

#### **4.7.0. Analysis of experimental data**

Experimental data were recorded then analysed for each case study. I recorded each scoping experiment and every successful experiment by photographing the experimental results then scanning the experimental results using an Umax Powerlock 11 Scanner then saved the scanned results in the computer program Photoshop 6. My methods of analysis involved in-depth sequential systemic visual examinations of the experiments of how photosensitive glass reacted when incorporated into a traditional glass making technique. I then printed out the

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<sup>36</sup> Yin (1994) suggested pattern-matching as another method of analysis. If the case study is an explanatory one, the patterns may be related to the dependent or independent variables. If it is a **descriptive** study, the predicted pattern must be defined prior to data collection.

scanned results of the experiments onto a comparative tabular format that can be consulted by any glass artist/designer.

#### **4.8.0 Perceived potential**

Having surveyed and identified many glass art making processes with potential to accommodate the incorporation of photosensitive glass into their production processes as case studies, I proceeded with my experimental research. I believed that there was potential in undertaking scoping experimentation within the selected traditional glass-making techniques so I systematically tested the relationship between the exposure times of the photosensitive glass scoping experiments in each case study, under controlled ultraviolet light conditions and controlled development temperatures in an electric kiln for certain lengths of time. This relationship was thought to hold the key for the potential use of photosensitive glass in traditional art-glass making techniques. These scoping experiments enabled me to add to and develop a range of alternative techniques for photosensitive glass, with a potential to be used as a representational medium and to obtain results that would contribute to the knowledge of glass design, glass art and alternative photography. Further experimentation followed the successful scoping experiments. These experiments were perceived as necessary so as to find a potentially more useful and comprehensive range of kiln firing temperatures. This step was taken because it was hoped that additional colours would be released that were currently hidden in the photosensitive glass body, other than pinks, mauves, reds and purples.

#### **4.9.0. Selecting the case studies**

The successful organizing and conducting of any case study research starts with determining and defining the research questions before the selection of the cases. Data gathering and analysis are then determined before collecting the actual data.

Once these steps have been taken evaluation and analysis of the data takes place (Sue Soy 1997, Spring). The primary question to be answered for this research was what were the traditional glass-making techniques that could be considered for acceptance of the incorporation of photosensitive glass and therefore increase their potential use? Once this question was answered I was able to select the seven case studies and their sub-categories that I considered to have the potential of having photosensitive glass being incorporated into their traditional art-glass making techniques. The data that I planned to gather and then to analyse were to be obtained from the actual scoping experiments and the final successful case study experiments. The next important question that I needed to address was at what stage in the various selected glass making techniques could I incorporate photosensitive glass? This question was answered by a review of the history of photosensitive glass and its standard application. A survey of the applications of photosensitive glass already being used in by glass artists/designers in traditional glass-making techniques was researched. My selection of the potential seven traditional glass making techniques was based upon my personal experience of the techniques that I used when I placed a photograph into a photosensitive glass plate for my Honours Degree in Design 2004. How the photosensitive glass was incorporated into the selected techniques was based on the many scoping experiments. The order of the selected techniques was based on the categories of art-glass working temperatures, such as Hot glass, Warm glass and Cold glass. Brad Walker (1999-2006) defines art glass as belonging to the three different types of glass activities. The three major glass activities are discussed in the following section.

#### **4.9.1. General categories of art-glass-making**

##### **Hot glass**

This activity involves working with a furnace at temperatures above 1100 degrees Celsius [2000 degrees Fahrenheit]. Hot-blown glass requires a close physical relationship with the medium in its molten state unlike kiln-formed glass where artists are able to assemble their works from cold components.

### **Warm Glass**

This activity involves working with a kiln at temperature between 600 to 925 degrees Celsius [1100 and 1697 degrees Fahrenheit].

### **Cold Glass**

This activity involves working with glass at room temperature. Examples are stained glass, glass carving and etching.

### **Lamp working/Bead making**

This activity/technique is often considered by some glass makers to be in the Warm Glass category while others consider lamp working to be a Hot Glass technique. There is controversy amongst glass artists over the activity of Lamp working/Bead-making being referred to as a Hot glass technique perhaps because flameworking is considered to be a super-hot activity. It involves making glass shapes such as small animals or for chemistry laboratory apparatus by flaming and softening glass using a gas and oxygen flame from a Bead-making burner.

Each selected potential case study was then assessed by me to determine how many sub-categories there were associated with its traditional art-glass making technique that I considered would be suitable for photosensitive glass incorporation. Following my assessment, each sub-category was then subjected to scoping experiments so that each sub-category could be assessed as to how many referable experiments would be needed to develop potential processes models from its successful outcomes. The relationship between the scoping experimentation on the traditional art-glass making techniques that I considered suitable for the incorporation of photosensitive glass and the actual case studies is clarified and discussed in Chapter Five. All the scoping experiments were photographed and the methods of making stages were then documented for future experimentation according to the sub-category of the potential case study. The successful scoping experiments are reported in Chapter Five. Once problems had been overcome, further scoping experiments were then carried out and if these proved to be successful they were recorded in the relevant case study. All unsuccessful scoping experiments were

also recorded. The sequence of stages, latent image ultraviolet light latent image development exposure and exposure to firing temperatures and the development of images and annealing in an electric kiln used in the development of the scoping experiments were recorded according to the sub-categories of the potential case study for reference. Only the successful scoping experiments and their accompanying firing schedules were re-tested as case studies in Chapter Five.

#### **4.9.2. Summary**

My research concentrated on examining and documenting photosensitive glass as a case study of materials research for art practice. My successful scoping experimentation led towards a series of case studies for analysis. Conclusions, recommendations and implications that were based on the evidence were recorded (Yin 1984).

The following traditional art-glass techniques that I considered suitable for the incorporation of photosensitive glass were further researched and Soy's (1997) suggested six steps were followed. The six steps were to determine and define the research questions, select the cases and determine data gathering and analysis techniques, prepare to collect the data, collect data in the field, evaluate and analyze the data, and then report the findings. Sue Soy (1997) writes that many well-known case study researchers such as Robert E. Stake, Helen Simons, and Robert K Yin have written about case study research and suggested techniques for organizing and conducting the research successfully. Yin (1994) identified six primary sources of evidence for case study research. The six sources identified were documentation, archival record, interview, direct observation, participant observation and physical artifacts.

The case studies with their sub-categories are listed in full below in the following tables. Each case study and its related sub-categories are more fully discussed in the scoping experiments in Chapter Five. The aim of the scoping experiments in chapter Five was to discover whether it was possible to incorporate photosensitive

glass into the selected techniques. The successful scoping experiments were then repeated and retested then documented as case studies in Chapter Six.

### 4.9.3. The potential case studies and their sub-categories

**Figure 18(a)**

Table 1. Case Study One: [pulling and drawing] (Hot glass).

Sub-category 5.1.1:	Pulling stringers, rods and canes. <sup>37</sup> .	Pulling furnace glass
Sub-category 5.1.2:	Making murrine <sup>38</sup> or mosaics.	Pulling furnace glass
Sub-category 5.1.3.	Pouring medallions <sup>39</sup> or cutting rods for Bullion or Crowns <sup>40</sup> .	Furnace glass

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<sup>37</sup>“ A cane is a thin rod of clear of coloured glass that is used to make the stems of certain types of drinking glasses or that is cut in slices and used in the manufacture of millefiori for paperweights or mosaic glassware” (Bray 2001, 65 ) taken from the Dictionary of Glass: materials and Techniques, 2<sup>nd</sup> edition.

<sup>38</sup> Definition of murrine: a single cross section chip of mosaic cane (Kerkvliet 1997).

<sup>39</sup> This was a technique used during the Bronze Age and or cameo techniques during the Roman times (Klein and Ward 1992, 10).

<sup>40</sup> Disks of glass made by spinning out a medallion into a bowl shape and flattening the shape (Bray 2001, 58).

**Figure 18(b)**

Table 2. Case Study Two: [crushing and recycling (Warm glass)]

Sub-category 5.2.1:	Chunk deVerre <sup>41</sup>	Large chips of glass
Sub-category 5.2.2:	Pate de Verre <sup>42</sup>	Paste of small glass chips.
Sub-category 5.2.3:	Recycled glass	Glass & other materials an industrial process. <sup>43</sup>

**Figure 18(c)**

Table 3 .Case Study Three: [Bead-making/Flameworking] (Hot glass)

Sub-category 5.3.1:	Bead-making <sup>44</sup>	A bead-making process
Sub-category 5.3.2:	Button making <sup>45</sup>	A bead-making process
Sub-category 5.3.3:	Core forming <sup>46</sup>	A bead-making process

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<sup>41</sup> Larger pieces or chips of glass fused together.

<sup>42</sup> A paste of ground glass that is fired like an enamel. Antonin Daum of France discovered a new art glass technique in the use of Pate de Verre (Klein and Ward 1992, 206).

<sup>43</sup> New Modes of Interdisciplinary work. Jim Roddis of Sheffield Hallam University, England pioneered a technique using concrete waste and glass for architectural projects. (Fazackerley A. The Times Higher. April 2005, 12).

<sup>44</sup> Beads were among the first objects made in glass and are thought to have appeared initially in the 3<sup>rd</sup> millennium BC. (Bray 2001, 46).

<sup>45</sup> “A button is officially an object that can be used to fasten garments” (Diana Hefti 1999).

<sup>46</sup> A bead making process for making hollow forms, first developed during the Bronze Age by the Phoenicians (Klein and Ward 1992,14).

**Figure 18(d)**

Table 4. Case Study Four: [kiln casting/slumping] (Warm glass)

Sub-category 5.4.1:	kiln casting/slumping <sup>47</sup>	Kiln work
Sub-category 5.4.2:	Simple open face Pate de Verre <sup>48</sup>	Kiln work

**Figure 18(e)**

Table 5. Case Study Five: [furnace casting] (Hot glass)

Sub-category 5.5.1:	Sand Casting <sup>49</sup>	Furnace glass
Sub-category 5.5.2:	Forcing hot molten glass into metal moulds to create beads.	Furnace glass
Sub-category 5.5.3:	Casting into a variety of moulds <sup>50</sup>	Furnace glass

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<sup>47</sup> Kiln casting is a general-purpose term that refers to the melting of glass inside a mould inside a kiln. It contains many of the elements of fusing and slumping but is generally more complicated and requires a greater understanding of warm glass principles (Walker, Brad.1999).

<sup>48</sup> Pate de Verre is sometimes used as a generic term for kiln casting, but it actually refers to a very specialized kind of casting (Walker, Brad.1999).

<sup>49</sup> The Pouring molten glass from the furnace in to special sand to produce sculptural forms (Bray 2001, 209).

<sup>50</sup> Casting molten glass from the furnace into a variety of moulds then annealing in a kiln (Bray 2001, 173).

**Figure 18(f)**

Table 6. Case Study Six: [free blown glass & blowing a bubble into a mould] (Hot glass)

Sub-category 5.6.1:	Free blowing <sup>51</sup>	Furnace glass
Sub-category 5.6.2:	Mould blowing <sup>52</sup>	Furnace glass

**Figure 18(g)**

Table 7. Case Study Seven: Acid etching<sup>53</sup>/Acid embossing (Cold glass)  
Hazardous

Sub-category 5.7.1:	Acid etching Acid embossing	Cold glass/corrosive technique
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Chapter Five illustrates, describes and discusses the results of the successful and unsuccessful scoping experiments in each potential case study.

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<sup>51</sup> The process of introducing air into glass for the purpose of forming hollow ware (Bray 2001, 80).

<sup>52</sup> Blowing into moulds is general practice. Most of the moulds used are either cast steel, graphite or wooden ( Bray 2001, 53).

<sup>53</sup> A process of matting or removing the surface of glass by exposure to hydrofluoric acid or its derivatives (Bray 2001, 113).

## CHAPTER FIVE – SCOPING EXPERIMENTS

### 5.0.0. INTRODUCTION

This chapter illustrates then describes and discusses the successful and unsuccessful scoping experiments and their outcomes. Each traditional glass-making technique was allocated a case study then the scoping experiments were recorded in the relevant sub-categories of their case studies.

- The master plan or protocol for my research consisted of a format in which full details of each case study's research design was made (see Figure 17 in Chapter Four)
- General rules and procedures about how the research was conducted as well as an overview of each case study are discussed
- The identification of range of experimental issues was addressed
- The overview of my protocol contained:
  1. The general topic of my inquiry
  2. The purpose of each case study
  3. It begins with the setting out in table form the seven traditional techniques that I estimated as having the potential for photosensitive glass to be incorporated
- These seven case studies are listed in order of difficulty of technical execution
- The next step was to divide the case studies into sub-categories or units so that they become units of analysis
- Each sub-category was then defined before being placed in its historical context
- Modern glass artists using the each sub-category's techniques were then listed
- How and why questions giving reasons why I thought these selected techniques were suitable for the incorporation of photosensitive glass

included details of the questions that acted as prompts for me, the investigator, as well as details of all the types of evidence that I required

- Propositions were derived from the how and why questions (helpful in focusing the study's goals. Not all studies need to have propositions. An explanatory study, rather than having propositions, would have a stated purpose or criteria on which the success will be judged (Yin 1994, 20).

### **5.1.0. Scoping Case Study One: [pulling and drawing] (Hot glass)**

There are three sub-categories that represent potential case studies

Sub-category 5.1.1: Pulling stringers, rods and canes. Figure 18(a) page 107.

Sub-category 5.1.2: Making murrine or mosaics. Figure 18(b) page 108.

Sub-category 5.1.3: Pouring medallions or cutting rods for Bullion or Crowns. Figure 18(c) page 108.

#### **Definition and stated purpose of the scoping experiments of Case Study One**

The purpose of the scoping experiments was to show how photosensitive glass can be incorporated into the simple technique of pulling and drawing out molten glass from a furnace using an iron rod (pontil /pun) by the glass making artist or glass blower. Glass artists define this simple technique as belonging to the Hot-glass activity.

#### **An overview of sub-category 5.1.1: Pulling stringers, rods and canes.**

Stringers are often referred to as '*ribbon*' glass. Ribbon glass is glass that has been pulled (like toffee) when still hot. The stringer or ribbon glass threads were often fused together to make a sheet of glass then this sheet was placed over a bowl-shaped mould and heated so that the sheet would slump over the bowl-shaped mould (Bray 2001, 65) taken from the Dictionary of Glass: Materials & Techniques, 2<sup>nd</sup> edition. Canes are rods of glass that are formed by pulling (drawing out) out shorter and thicker threads of hot glass from the hot furnace using a pontil or punty iron. Sometimes canes of different colours were bundled together and fused into rods, then heated and pulled out again before being cut

into small decorative pieces to make millefiori for picking up in and putting into paperweights. Many variations of making canes used for opaque twists and filigree work existed and still exist.

**Research question (and specific hypothesis) that was applied to each sub-category of the scoping case study**

How can photosensitive glass be incorporated into the technique of pulling stringers, canes and rods?

**Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of pulling stringers, rods, and canes were subjected to several random methods that I referred to as scoping experiments.

**Hypothesis applicable for pulling glass stringers**

It is postulated that there is a relationship between the exposure times of the photosensitive glass stringers and canes of a specific thickness under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln.

**Objectives**

My objective in using stringers, canes and rods was to investigate and produce evidence of the potential for the incorporation of photosensitive glass into this ancient glass making technique by combining this photosensitive glass technology of the 1950's together with the adaptation of old alternative photographic printing processes of the late 19<sup>th</sup> century. To achieve this objective, I needed adequate resources such as time, paper, a digital scanner, a digital camera, access to a hot glass furnace and other glass making equipment, annealing kiln. I also developed a procedure for discussing my research with other glass makers and I needed to make a plan to adequately collect and record the data produced from my experimental work.

## **History**

This traditional glass-making technique belongs in the Ancient Glass making processes category. Fine work was produced by the Venetian glass blowers who incorporated a network of threads into various glass forms. One of these forms was bowls made using this process are called '*reticella bowls*' (Bray, 2001, 65, 201).

## **Contemporary Glass-Artists using Stringers**

Contemporary glass artists using some of these traditional glass-making techniques are Klaus Moje (Australia), Estelle Dean (Australia), "Toots" Zinsky (USA).

**The focus** on the technique of pulling hot glass was on its simplicity of execution by a novice glass-maker. It is a fairly simple activity, like pulling hot toffee and does not require blowing expertise; however, access to a hot glass furnace is necessary. An assistant would be an asset but not essential.

## **Identification of a range of experimental issues**

My experimental issues in the main were having access to a hot glass furnace and a reliable supply of photosensitive glass rods. Storage of the scoping experiments away from ambient ultraviolet light in the studio was a slight problem but was adequately solved by placing them into black photographic light excluding plastic bags and storing them in a secure dark cupboard until they were ready for the ultraviolet light exposure stage.

### 5.1.1. Scoping experiments for Case Study One

**Figure 19:** Group of Stringers

Scoping Experiment A: Sub category 5.0.1: Pulling the photosensitive stringers.



**Discussion of Scoping Experiment A: sub-category 5.1.1** as seen in the above illustration

Assorted thicknesses of pulled photosensitive glass were exposed to ultraviolet light for intervals in time related exposure tests. Sections of the stringer or cane were blocked off from ultraviolet light exposure by using the subtractive photographic exposure method.

#### **Results**

Scoping Experiment A was considered to be successful.

The process of making and pulling the stringers can be seen in Appendix Bi (Chapter Five) scoping Case Study One.

### **Case Study Project Aims**

This case study's aims were to research how to incorporate photosensitive glass into the traditional hot glass technique of pulling and drawing by using as many innovative methods as possible, so as to provide new opportunities to produce a novel way of working for glass artists/photographers.

### **Issues: Physical Issues**

Physical issues were mostly related to the access of a hot glass facility so as to use the hot molten glass in the furnace. Applications or incorporations of photosensitive glass to the pulling technique needed to be systematic and done in logical order so as to save hiring time at the furnace. One of the major issues was the degree of daylight present in the studio around the furnace while the molten glass was being pulled. This was an important issue as photosensitive glass must not be exposed to ambient ultraviolet light before being exposed to ultraviolet light under controlled conditions. Annealing was another issue - Stone (2000) advised that rods and canes thicker than a finger should be annealed directly after being made. Stringers do not require annealing because of their thinness. The storage of the stringers, rods and canes was an issue which I managed to solve by sliding them while still hot into a warmed up metal cylinder. When the stringers had cooled down, I transferred the batches of pulled photosensitive glass stringers into light-proof cardboard cylinders and stored them in black photographic plastic bags until I needed to use the stringers in my experiments. This activity took place under safe red photographic light.

### **Theoretical Issues: Bias**

In general glass-artists are generous in '*showing off*' their technical expertise when practicing their art. Openness about revealing all the information that might reflect poorly on the research should be a priority and the difficulties about

disclosing important feelings must be overcome (Lubbe 2003). My research was openly discussed with many of the practicing glass artists that I had the pleasure of observing and sometimes assisting. However, only a few expressed an interest in the technical methods of how I would go about achieving my objectives. Their general reasons for not wanting to know the finer details of how the experiments were carried out were in their opinion was that it was too time consuming to have to carry out experiments to achieve the results they desired. However, many of the glass-artists/designers with whom I interacted stated that they would be interested in my experimental results provided that they could be easily applied to the particular techniques they used. Subjectivity of interpreting the data after it has been written down can become a problem. Bias can be minimized and the onus is on the researcher to minimize the bias level (Stake 1994).

#### **Overview of sub-category 5.1.2: making murrine or mosaics.**

##### **The stated purpose of the scoping case study**

The purpose of this case study was to show how photosensitive glass could be incorporated into the simple ancient technique of making murrine or mosaics. Instead of using many pieces of colored glasses into a murrine as was traditional, only one type of glass need be used. The advantage of using photosensitive glass was photosensitive glass murrine could have images or motifs exposed into the glass body by exposure to ultraviolet light then heat developed and could then be used in a similar way as conventional murrine is used. The making of murrine or mosaics is considered by glass makers to be a simple process for a novice glass-maker. The process that I used is described in Appendix Bi (b) (Chapter Five) scoping Case Study One, sub-category 5.1.2: making murrine or mosaics.

##### **Definition of the sub-category**

Definition of murrine (a single cross section chip of mosaic cane).

*“This is a cane made by layers of hot bits of colours, or by fusing together preformed components that are then pulled and when cool cut up into sections. The name is said to be derived from the ancient murrhine bowls or the Italian*

*word murra*” (Kerkvleit 1997). These small sections are often referred to as mosaic canes. The results of these fusions were ground then fire-polished before being slumped into/or over a bowl shape. This activity involves working with molten (hot glass) and with glass at room temperature (cold glass).

**Research question (and specific hypothesis) that was applied to sub-category 5.1.2 murrine**

How can photosensitive glass be incorporated into murrine making techniques?

**Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of making murrine were subjected to several random methods that I refer to as scoping experiments.

**Hypothesis applicable to subcategory 5.1.2: making murrine**

It is postulated that there is a relationship between the exposure times of the photosensitive glass murrine under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln. This relationship determined the colour results.

**Objectives**

My main objective in making murrine was to investigate and produce evidence of the potential for the incorporation of photosensitive glass into this ancient glass making technique. To achieve this objective, I needed similar resources as discussed for making stringers, canes and rods.

**History**

Murrine is an ancient decorative technique used by the Romans and refined by the Venetians. The name murrine is said to be derived from the ancient murrhine bowls or the Italian word *murra* (Kerkvliet 1997). Murrine consist of canes of glass made up with layers of hot bits of coloured stringers or ribbon glass, fused

together then pulled before being cut into small sections. These small sections are often referred to as mosaic canes and were used in the 15<sup>th</sup> century BC. Vessels were made by placing the small sections onto a suitable fireclay forms then fusing the mosaic pieces together. The results of these fusions were ground then fire-polished before being slumped into/or over a bowl shape. The square shaped opaque glass mosaics are called tesserae, and were used on the walls of the Basilica in Aquilea near Udine, inland east of Venice and the Byzantine Basilica of Ravenna and many other Byzantine churches. In the middle of the 19<sup>th</sup> century, the lamp-worker Giacomo Franchini used a variation of the ‘hot’ method to create extraordinary portraits of leading political figures of his day. The component parts of the portraits consisted of various elements that were made into canes which were fused then reheated and stretched to reduce the scale of the portrait image. Once the cane had cooled it was sliced and each slice revealed a miniature portrait (Hulet 2004).

### **Contemporary Glass-Artists using the murrine technique**

Contemporary glass artists using some of these traditional glass-making techniques are Klaus Moje (Australia), Nicholas Mount, (Australia), Richard Marquis (USA), Dinah Hulet (USA) Brian Kerkvliet (USA), Estelle Dean (W.Australia. Giles Bettison (Australia). Nicholas Mount first learnt how to make murrine from Richard Marquis, who is a virtuoso master of the technique and uses it as a decorative motif in much of his work Murrine can be made extremely finely to create dazzling intricate patterns, as in the work of Australian glass artist Giles Bettison. Mount’s approach was entirely different. He composed his murrine as minimalist abstract fields of black on black and grey on grey. These murrine were stretched and flowed around simplified blown forms, each outline in a fine bleed of yellow (Osborne 2002, 20).

### **Identification of range of experimental issues**

My experimental issues were similar to those that I described in sub-category 5.1.1. Stringers

**Figure 20: 5.1.2c: Scoping Experiment C: Photosensitive glass murrine**



1.UV exposure for 80 minutes.  
Heat development @550 deg.Celsius for 271 minutes.

2.UV exposure for 80 minutes.  
Heat development @ 600 deg. Celsius For 271 minutes.



3.UV exposure for 80 minutes.  
Heat development @ 655 deg. Celsius for 271 minutes.

4.UV exposure for 80 minutes.  
Heat development @ 700 deg. Celsius for 271 minutes.

**Discussion of scoping experiment as seen in Figure 20**

Four separate groups of clear photosensitive glass canes were cut up into small lengths using a pair of pliers. They were then placed alongside one another, standing upright before exposing them to ultraviolet light for eighty minutes. This exposure time was based on the scoping experiments made on the group of

stringers and canes that were pulled in sub category 5.0.1. Each group of ultra violet light exposed murrine was then heat developed in an electric kiln at different temperatures but for the same length of time as the canes and stringers. The process describing the making of the murrine can be seen in Appendix Bi (b) (Chapter Five), scoping Case Study One.

### **Results**

1. The group of murrine that was ultraviolet light exposed for 80 minutes, heat developed @ 550 degrees Celsius for 271 minutes exhibited a pale clear mauve colour with no distinguishing centre.
2. The group of murrine that was ultraviolet light exposed for 80 minutes, heat developed @ 600 degrees Celsius for 271 minutes exhibited red centres surrounded by clear glass and remained separate from one another.
3. The group that was ultraviolet light exposed for 80 minutes, heat developed @ 655 degrees Celsius for 271 minutes showed evidence of a dull red colour, melting together in necklace strands.
4. The group that was ultraviolet light exposed for 80 minutes, heat developed @700 degrees Celsius for 271 minutes exhibited a dull ox-blood red colour. The individual murrine were all melted together in one bumpy mass.

### **Focus**

The focus on making murrine was on its simplicity of execution by a novice glass-maker. It is a fairly simple activity, like pulling hot toffee then cutting the cane or stringer up into short lengths. Making murrine does not require blowing expertise however, access to a hot glass furnace is necessary.

### **Conclusion**

Scoping experiment B using crushed photosensitive glass and furnace glass was unsuccessful. These scoping experiments indicate that heat development at temperatures higher than 600 degrees Celsius show that overheated photosensitive glass will exhibit dull red (haematone) '*over-cooked*' pieces.

### **Scoping Case Study Project Aims**

This case study's aims were to research how to incorporate photosensitive glass into the traditional murrine making technique by using as many innovative methods as possible, so as to provide new opportunities to produce a novel way of working with murrine for glass artists/photographers.

### **Issues**

#### **Physical Issues**

One of the major issues was the degree of daylight present in the studio around the furnace while the molten glass was being pulled. This was an important issue as photosensitive glass must not be exposed to ambient ultraviolet light before being exposed to ultraviolet light under controlled conditions. Annealing the murrine - Graham Stone (2000) advised that rods and canes thicker than a finger should be annealed directly after being made. Murrine do not require annealing because of their thinness. The storage of the pieces of unexposed murrine to ultra violet light was another issue which I managed to solve by cutting them up using pliers working under safe red light then storing them in a light proof container.

#### **Theoretical Issues**

Bias was discussed in sub-category 5.1.1., page 117 and 118 and is applicable to this sub-category.

**Overview of sub-category 5.1.3:** Pouring medallions or cutting rods to make medallions, Rondels, cylinder flat glass, Crowns or Bullions<sup>54</sup> for scoping Case Study One.

### **The stated purpose of sub-category 5.1.3**

The purpose of this case study sub-category was to show how photosensitive glass could be incorporated into the ancient technique of making Rondels, Cylinder flat glass, Crowns or Bullions. Instead of using many pieces of coloured glasses in a Crown or Bullion only one type of glass need be used. The photosensitive glass Crowns or Bullion could have images or motifs exposed into the glass body by exposure to ultraviolet light then heat developed and could then be used in a similar way as conventional Crowns or Bullion are used.

### **Definition of sub-category 5.1.3: Crowns or Bullions**

Crowns or Bullions are circular flat pieces of glass that have been spun out on the end of a punty (pontil) iron.

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### **Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of making or spinning Crowns or Bullions were subjected to several random methods that I referred to as scoping experiments.

### **Hypothesis applicable to subcategory 5.1.3: Crown or Bullion making**

It is postulated that there is a relationship between the exposure times of the photosensitive glass Crowns or Bullion of a specific thickness under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln.

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<sup>54</sup> Disks of glass made by spinning out a medallion into a bowl shape and flattening the shape (Bray 2001, 58) taken from the Dictionary of Glass: Materials and Techniques, 2<sup>nd</sup> edition. 2001.

## **Objectives**

The objective in making photosensitive Crowns or Bullions was to be able to place designs directly into the Crowns as an alternative to using pieces of coloured glass as done in the lead lighting technique.

## **History**

Solid lengths of circular intensely coloured clear or opal glass were made into rods for medallion cutting, also known as 'Kugler' colours, named after Klaus Kluger of Augsburg, Germany. Rondels or Bullion were the major source of sheet glass for many centuries. Small panes were cut out from the crown. Because they were made directly from blown and spun glass, they were much more brilliant than the other forms of sheet glass which were available (Bray 2001, 202). Flat mouth-blown cylinder glass was developed in the Seine and Rhine areas of France and Germany. The climate and the increase in the number of windows required in mediaeval times were two of the many reasons that glass was used in windows in buildings. Two methods for making window glass was used, the crown method and the cylinder method. The Romans used glass that had been cast on a plate for their window glass.

Tatra Glass (UK) was formed in 1990 specifically to import antique glass, bullions and roundels from Poland. A glazing division, Quorn Glass, was formed in 1992, which in 1994-1995 re-glazed over 2000 square metres of clear restoration antique glass in Somerset House, London. New premises were purchased in 1999 together with a glazing company in Loughborough and the factory is now known as Quorn and Company in Loughborough, England.

## **Contemporary Artists using this traditional technique**

Jasper Dowding (Perth WA). Tatra Glass (UK).

### **Identification of a range of experimental issues**

My experimental issues in the main were setting up collaboration with an experienced glass blower and access to a hot glass furnace and a reliable supply of photosensitive glass rods. Annealing of the photosensitive crowns or bullions was an issue as a separate annealing kiln for the general annealing kiln was important so as to prevent accidental exposure to daylight when it was opened and unpacked. Photosensitive crowns and bullion have to be unpacked under safe red photographic light. Storage of the scoping experiments away from latent ultraviolet light in the studio was a problem.

### **Focus**

The focus of sub-category 5.0.3. was to have available a supply of photosensitive Crowns or Bullions ready for placing images or motifs into the glass body.

**Process** (standard applications) **and technical skills required** can be found in Appendix Bi (c) (Chapter Five) scoping Case Study One

### **Scoping Experiments**

Scoping experiments for making photosensitive Rondels, Crowns or Bullion were discontinued because glass artist Jasper Dowding who was collaborating with me during the scoping stage of had to find work as a cartographer based in Newman in the north of Western Australia due to the economic down-turn of 2008/9.

### **Scoping Case Study Project Aims**

This sub-category project aims were to research how to incorporate photosensitive glass into the traditional hot glass technique of blowing Crowns or Bullions by using as many innovative methods as possible, so as to provide new opportunities to produce a novel way of producing Crowns or Bullions for architectural use by glass artists/photographers.

## **Issues**

### **Physical Issues**

Physical issues were mostly related to the access of a hot glass facility so as to use the hot molten glass in the furnace. Applications or incorporations of photosensitive glass into the blowing technique needed to be systematic and done in logical order so as to save hiring time at the furnace. One of the major issues was the degree of daylight present in the studio around the furnace while the molten glass was being blown or spun out. This issue was an important issue as photosensitive glass must not be exposed to latent ultraviolet light before being exposed to ultraviolet light under controlled conditions. Annealing was another issue because of the sizes of the Crowns or Bullion. Graham Stone's (2000) annealing tables were consulted and applied.

### **Theoretical Issues**

Bias was discussed in sub-category 5.1.1., page 117 and 118 of this thesis and is applicable to this sub-category.

## **Conclusion**

Figure 20: Scoping experiment A: sub-category 5.1.1: Pulling the photosensitive stringers was considered successful for further experimentation to be conducted  
Scoping experiment C: sub-category 5.1.2: Making murrine was considered moderately successful enough to warrant further experimentation.

Scoping experiments for sub-category 5.1.3: Crowns or Bullion were temporarily discontinued.

## **5.2.0. Scoping Case Study Two: [crushing and recycling] (Warm glass)**

There are three sub-categories that represent potential case studies.

Sub-category 5.2.1 Chunk de Verre<sup>55</sup>. Figure 18(b) page 108.

Sub-category 5.2.2: Pate de Verre<sup>56</sup>. Figure 18(b) page 108.

Sub-category 5.2.3: Recycled glass combining glass and other materials – an industrial process<sup>57</sup>. Figure 18(b) page 108.

### **Introduction**

Assorted chips of photosensitive glass off the moyle (a section of a glass blower's blowing pipe) were collected for the purpose of determining whether it was possible to recycle blown photosensitive glass. The experimental issues of using recycled photosensitive glass are discussed in the two sub-categories Chunk de Verre and Pate de Verre in potential Case Study Two.

### **A general overview of my research project inquiry into**

#### **5.2.0. Scoping Case Study Two [crushing and recycling] (Warm glass)**

Sub-category:5.2.1.Crushing re-cycled photosensitive glass into large chips for Chunk de Verre.

### **Definition**

Chunk de Verre is the name I have given to the technique when larger pieces or chips of glass are fused together in an electric kiln. The technique is similar to that of Pate de Verre.

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<sup>55</sup> Larger pieces or chips of glass fused together.

<sup>56</sup> A paste of ground glass that is fired like an enamel. Antonin Daum of France discovered a new art glass technique in the use of Pate de Verre (Klein and Ward 1992, 206).

<sup>57</sup> New Modes of Interdisciplinary work. Jim Roddis of Sheffield Hallam University, England pioneered a technique using concrete waste and glass for architectural projects. (Fazackerley A. The Times Higher. April 2005, 12).

### **Stated purpose of the scoping Case Study**

The purpose of scoping Case Study Two is to show how photosensitive glass can be incorporated into the simple technique of crushing chunks of glass to make Chunk de Verre.

### **Overview of sub-category 5.2.1: Chunk de Verre**

**Research question** (and specific hypothesis) **that was applied to sub-category 5.2.1.**

- How might photosensitive glass be recycled?
- What methods can I apply to incorporate photosensitive glass into the technique of Chunk de Verre (medium to large chips of glass off the moyle)?
- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was making Chunk de Vere?

### **Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of crushing the recycled photosensitive glass chips were subjected to several methods that I referred to as scoping experiments.

**Hypothesis applicable to subcategory 5.2.1: Chunk de Verre** (Crushing and recycling photosensitive glass)

It is postulated that the positioning of a photosensitive Chunk de Verre scoping experiment under the two ultraviolet light tubes situated in the top of the light-box should give different colour density results when placed on a rotating turntable compared with the results from a non-rotating turntable. In addition it is postulated there is a relationship between the exposure times of the crushed re-cycled photosensitive glass chunks under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln. Colour variations could be designed for exact placement on a prototype using a

non-rotating turntable under ultraviolet light whereas uniform colour exposure designs should result from the rotating turntable.

### **Objectives**

The objective of these experiments was to determine if there would be any difference in colour saturation results of the recycled photosensitive glass taken from the moyle (blowing pipe) when exposed to ultraviolet using a non-rotating turn table compared with a rotating turntable after heat development in an electric kiln using a HARCO digital controller. The second purpose of these experiments was to determine the timing of ultraviolet light exposure most likely to give the optimum exposure results when using a rotating turntable or a static the turntable. The third objective was to determine the optimum heat development temperature required to develop the latent ultraviolet light exposed image using crushed recycled photo sensitive glass off the moyle.

### **History**

Fusing chunks of recycled photosensitive glass together was an experimental recycling technique that came about when I decided to collect the discarded photosensitive glass off the moyle, expose the pieces under ultraviolet light for a set number of minutes then heat develop the ultraviolet exposed glass at a pre-determined temperature for a certain length of time and fuse them together in an electric kiln. This recycling experimentation I refer to as '*Chunk de Verre*' so as to distinguish it from '*Pate de Vere*'.

### **Modern glass artists using this technique**

A literature search was undertaken and no information could be found indicating that this recycling technique was being used by other glass-artists.

### **Identification of a range of experimental issues**

- Access to shards of photosensitive glass that could be used for re-cycling
- Space for crushing glass and space for storing crushed glass

- A Flat-bed kiln for fusing the chunks of recycled glass together
- A HARCO digital controller for temperature measurement and timing of experimental firing of the flat bed kiln.

### **The focus of this sub-category**

The focus of scoping Case Study Two, sub-category 5.2.1., was on its simplicity of execution and to determine if there would be any difference in colour saturation results of the recycled photosensitive glass taken from the moyle (blowing pipe) when exposed to ultraviolet using a non-rotating turn table compared with a rotating turntable after heat development in an electric kiln using a HARCO digital controller.

**Process** (Standard applications) **and technical skills required can be seen in Appendix Bii(a)** (Chapter Five) scoping Case Study Two: sub category 5.2.1: Chunk de Verre.

### **Results**

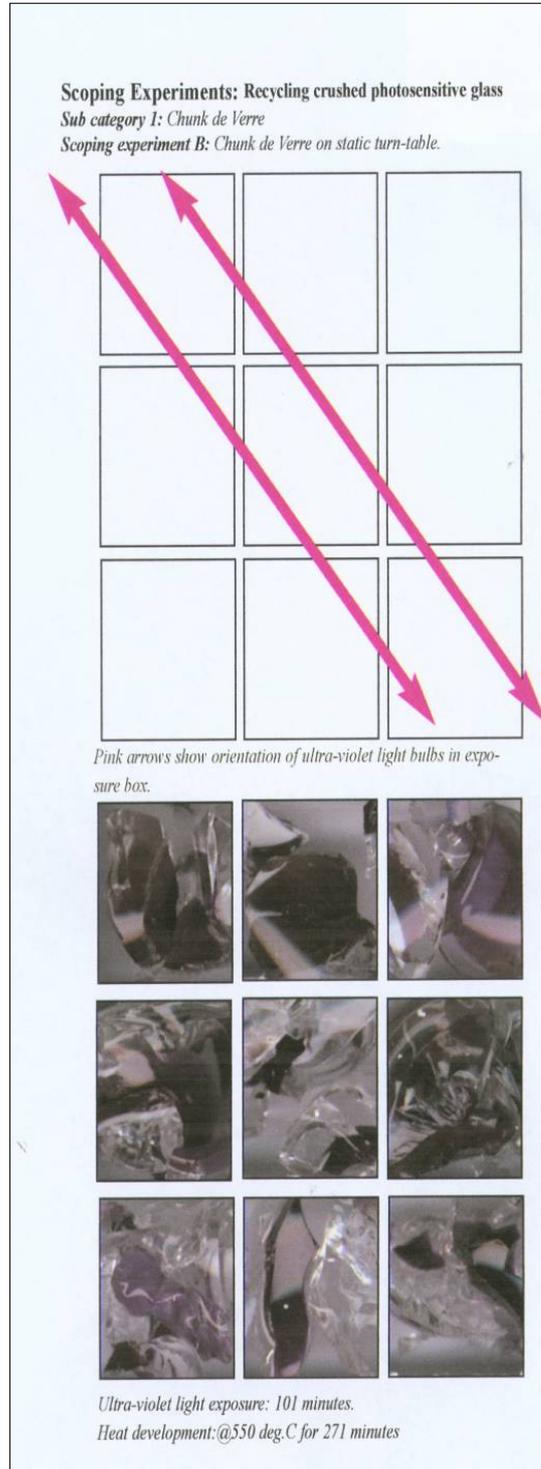
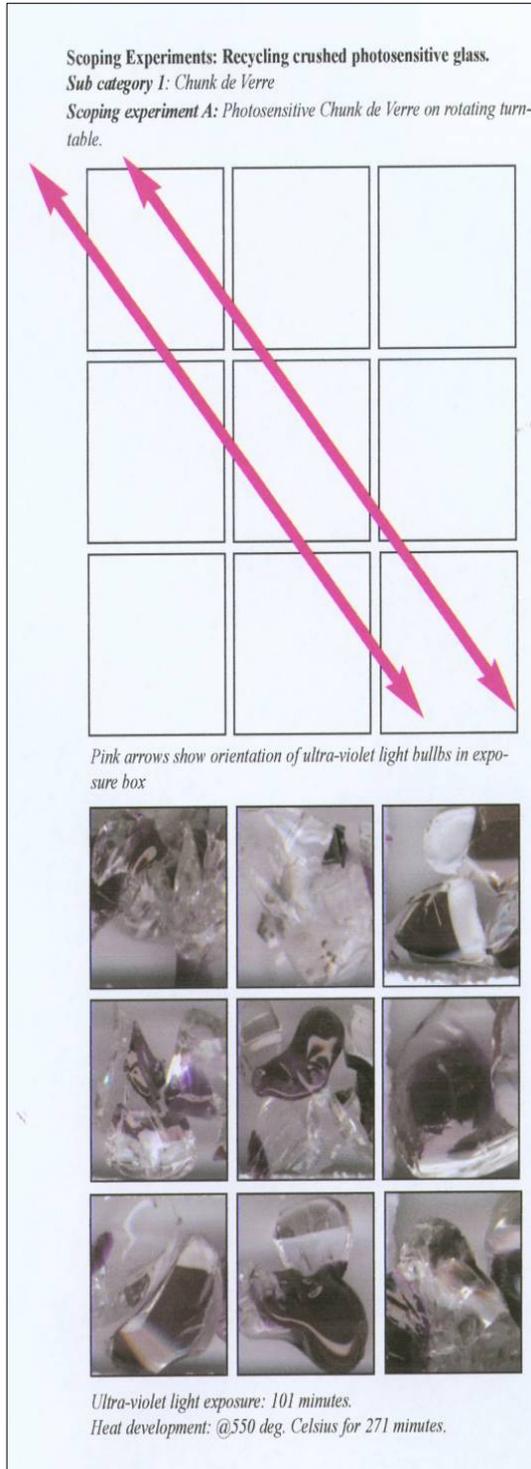
Comparisons between non-rotating and rotating turntable results to show that relative values were made and it was observed that scoping **Experiments A** and **B** that were exposed to ultraviolet light on rotating and static turntables for 101 minutes then heat developed in a HARCO Digitally controlled electric kiln @ 550 degrees Celsius for 271 minutes did not show any difference in saturation colour results between non-rotating and a rotating turntable ultra violet light exposure for 101 minutes, see figures No.21 and No.22. However, scoping **Experiment D** consisting of crushed photosensitive Chunk de Verre glass chips that were exposed for 60 minutes and heat developed at 550 degrees Celsius for 271 minutes on a non- rotating table had darker saturated colour results at numbers 1, 5 and 9. See figure No 23 than scoping **Experiment C**, see figure No.24, whose chips were exposed to ultraviolet light for 60 minutes under a rotating turntable then heat developed for the same temperature and time.

**5.2.1. Scoping Experiment E (the control):** shows a comparison between photosensitive chunk de Verre Chips made using clear soda lime glass and (the

variable) Opal white glass used in addition with the photosensitive glass chips exposed under ultraviolet light for 90 minutes, 100 minutes and 110 minutes on a static turntable then heat developed @ 600 degrees Celsius for 271 minutes.

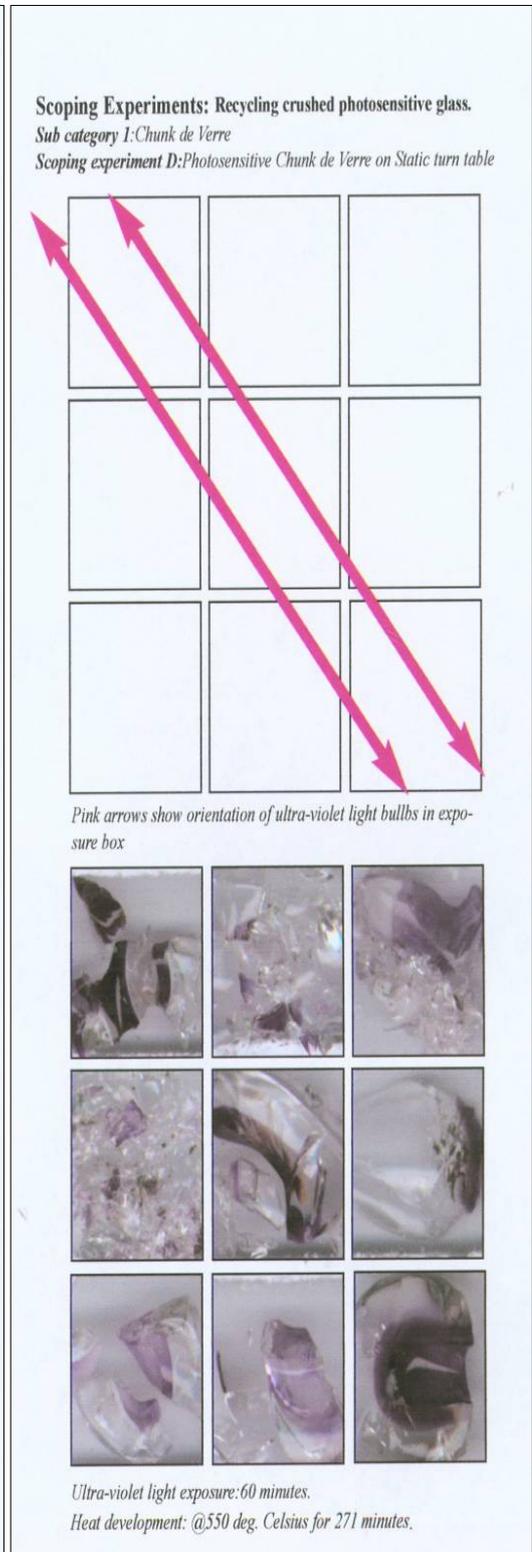
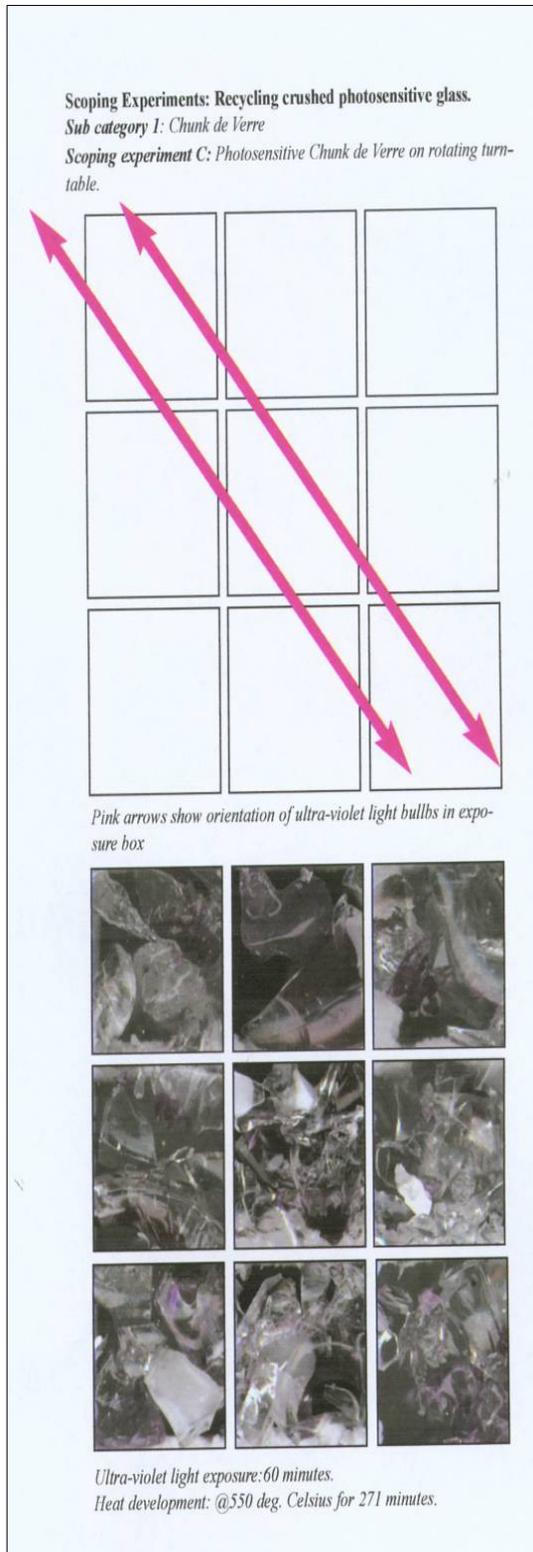
**Figure 21: Scoping Experiment A**

**Figure 22: Scoping Experiment B**



**Figure 23: Scoping Experiment C**

**Figure 24: Scoping Experiment D**



**Figure 25: Scoping Experiment E**

**Scoping Experiments: Recycling photosensitive glass**

*Sub category 1: Chunk de Verre*

*Scoping experiment E: The photosensitive glass control and the comparative dependent variable.*

*Ultraviolet-light exposed from 90 minutes to 110 minutes.*

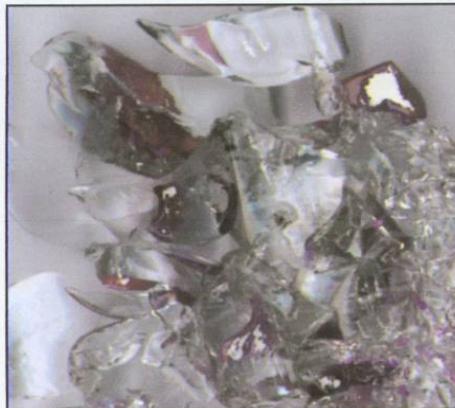
*Heat developed @600 deg.Celsius for 271 minutes in an electric kiln.*



*1. Control: UV light exposed 90 minutes.*



*2. Variable: UV light exposed 90 minutes.*



*3. Control: UV light exposed 100 minutes.*



*4. Variable: UV light exposed 100 minutes.*



*5. Control: UV light exposed 110 minutes.*



*6. Variable: UV light exposed 110 minutes.*

## **Results**

The results of the comparison between the control and the variable in **scoping Experiment E**, figure No. 25 show that in the experimental variable, the range of colours is broader than in the control.

## **Conclusion**

The results indicated that further experiments involving shorter ultraviolet light exposures on a non-rotating turn table and then heat developed at lower temperatures for a shorter length of time would give similar results to the experiment that was heat developed at 550 degrees Celsius and ultraviolet light exposed for 60 minutes on a non-rotating turn table. Possible improvements in techniques used were considered and at this stage I decided that Line blending and/or Triaxial blending of crushed photosensitive glass pieces may give more controlled and informative results.

## **Issues**

Physical Issues and theoretical issues were similar to those discussed on pages 117 and 118.

## **Overview of sub-category: 5.2.2. Scoping Case Study Two: Crushing recycled photosensitive glass into chips for Pate de Verre**

Pate de Verre is a popular art glass technique that was discovered by Antonin Daum of France in the late 19<sup>th</sup> century. The technique is a paste of ground glass that is fired like an enamel glaze (Klein and Ward 1992, 207).

## **Definition**

Translated from the French language, Pate de Verre means a paste of ground glass.

*“The term has now become generally accepted as describing a wide range of cast glass objects which, strictly speaking, bear little resemblance to the concept of glass pastes. Some of them could be legitimately called ‘pate de verre’ as they*

*are produced by a process of sintering glass grains together in a suitable mould but many others result as very solid objects from more general casting techniques” (Bray. 2001,182).*

### **Stated purpose of the scoping case study**

The purpose of scoping Case Study Two was to show how photosensitive glass can be incorporated into the simple technique of crushing chunks of glass to make Pate de Verre.

### **Research questions (and specific hypothesis) that was applied to sub-category 5.2.2. Pate de Verre**

What methods can I apply to incorporate recycled photosensitive glass into the traditional technique of Pate de Verre (paste of glass) that has been crushed?

### **Solution**

By applying the experimental form of the scientific method, the techniques of crushing the recycled photosensitive glass were subjected to several random methods that I referred to as scoping experiments.

### **Hypothesis applicable to sub-category 5.2.2.**

Crushing and recycling photosensitive glass

It is postulated that the positioning of a photosensitive Pate de Verre scoping experiment under the two ultraviolet light tubes situated in the top of the light-box should give different colour density results when placed on a rotating turntable compared with the results from a non-rotating turntable. In addition it is postulated there is a relationship between the exposure times of the crushed recycled photosensitive glass chunks under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln. Colour variations could then be designed for exact placement on a prototype using a non-rotating turntable under ultraviolet light whereas uniform colour exposure designs should result from the rotating turntable.

## **The Objectives**

### **Scoping Experiments for Pate de Verre - Colour Saturation**

The primary aim of these experiment was to determine if there would be any difference in colour saturation results of the recycled crushed photosensitive glass taken from the moyle (blowing pipe) when exposed to ultraviolet using a non-rotating turn table (static turn table) under a light box compared with a rotating turntable after heat development in an electric kiln using a HARCO digital controller as was found in the experiments using Chunk de Verre.

### **Ultraviolet light exposure timing**

The second purpose of the scoping experimentation was to determine the timing of ultraviolet light exposure most likely to give the optimum exposure results when using a rotating turntable or a non-rotating (static) turntable.

### **Optimum heat development temperatures**

The third objective was to determine the optimum heat development temperature required to develop the latent ultraviolet light exposed image using crushed recycled photo sensitive glass off the moyle.

## **History**

The Egyptians and Phoenicians used glass pastes for making forms since the manufacture of pre-blown glass. At the time of the Art Nouveau movement, a group of artists working at the School of Nancy were very influential in France around the end of the 19<sup>th</sup> century and the beginning of the 20<sup>th</sup> Century, revived this glass paste method. Antonin Daum, son of founder Daum et Cie, Cristallerie de Nancy was greatly influenced by Emile Galle, son of a glassmaker from Nancy. Antonin Daum experimented with innovative styles and techniques. His experiments with vitrified powders led to two important discoveries. The first was seen in a series of opaque vases known as *ceramique de jade* but the second discovery turned out to be more far reaching. This technique was called *Pate de Verre*, from which sculpture could be moulded. Henry Daum called Pate de Verre, the greatest discovery of our time in art glass, never hinted at in glass-making of any previous period, and a discovery France can be proud of. Cros was

interested in the ancient Roman and Egyptian coloured-glass sculptures and this interest led him to research the techniques used by these early crafts-men. He experimented with ground glass mixed with a binding agent. In 1894 he completed his first large panel “L’Histoire de L’eau”. In 1900, a second panel “L’Histoire de Feu” was completed and is now in the Museum of Decorative Arts in Paris (Klein and Ward 1992, 206). Francois Decorchement and Gabriel Argy-Rousseau were some of the artists who revived this technique. Other artists who became involved included Albert Dammouse, George Despret, Ringel d’Illzach, Almeric Walter and Henry Cros’s son Jean (Kohler 1998, 16).

**Process (Standard applications) and technical skills** required can be seen in Appendix Bii (b) (Chapter Five) scoping Case Study Two: sub-category 5.2.2.

Pate de Verre. Additional Figures can be viewed in Appendix Bii (b) (Case Study Five) scoping Pate de Verre. All of the above scoping experiments were exposed to ultraviolet light for 60 minutes. Heat development for these scoping experiments ranged from 575 to 600 degrees Celsius on non-rotating (static) and rotating turntables.

#### **Contemporary glass artists using these techniques are**

Judith Bohm Kerr (Queensland), Dan Daly (USA), Edris Eckhardt (USA), Estelle Dean (Perth, WA), Gerry Handley, (Perth, WA), Belinda Kay (Perth WA).

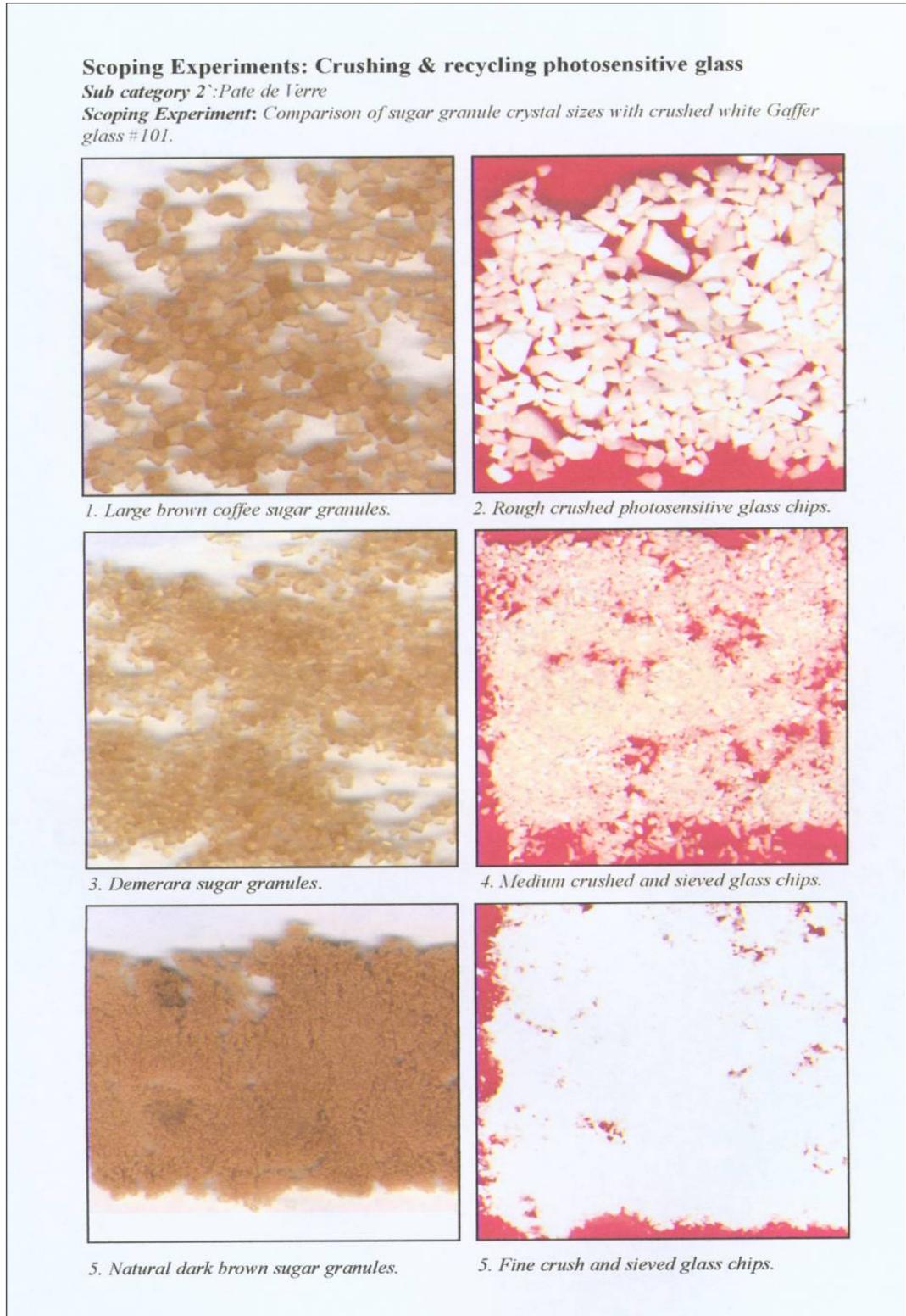
#### **Identification of a range of experimental issues**

My experimental issues for this sub category were access to shards of photosensitive glass that could be crushed and used for making Pate de Verre, space and equipment for crushing and storing the recycled photosensitive glass.

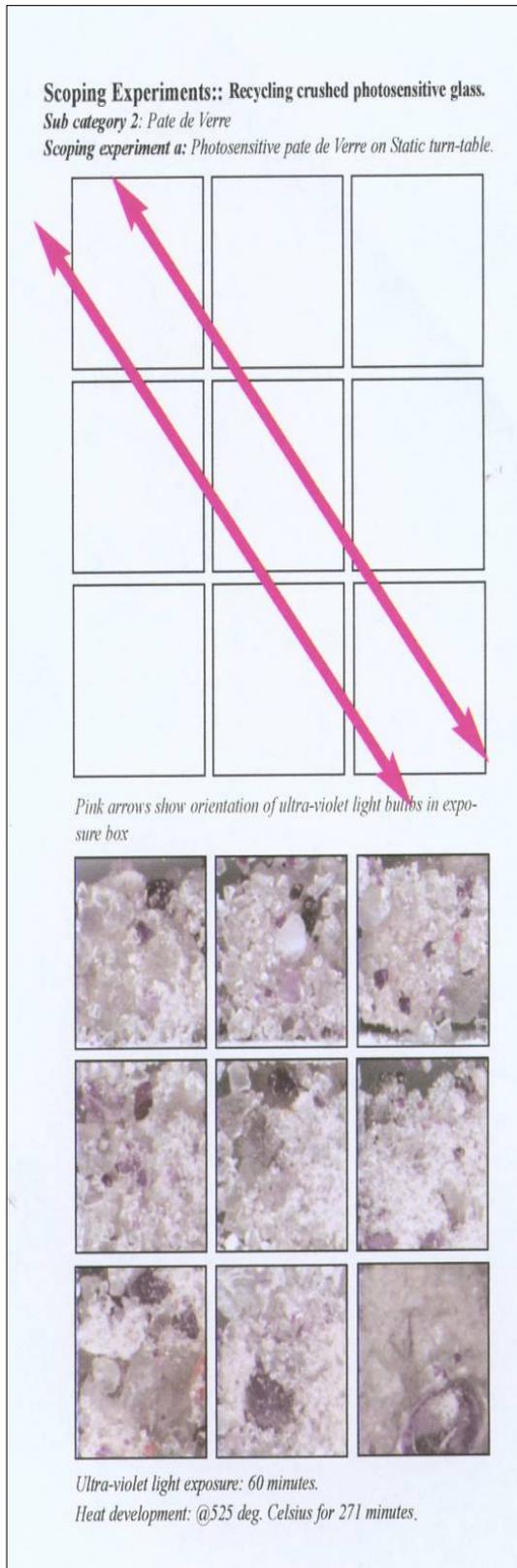
#### **The focus**

In order to determine the optimum sizes of ground or crushed glass to be used in the Photosensitive Pate de Verre experimentation, I decided to base the sizes of crushed photosensitive glass on natural brown sugar granules, see figure No.26.

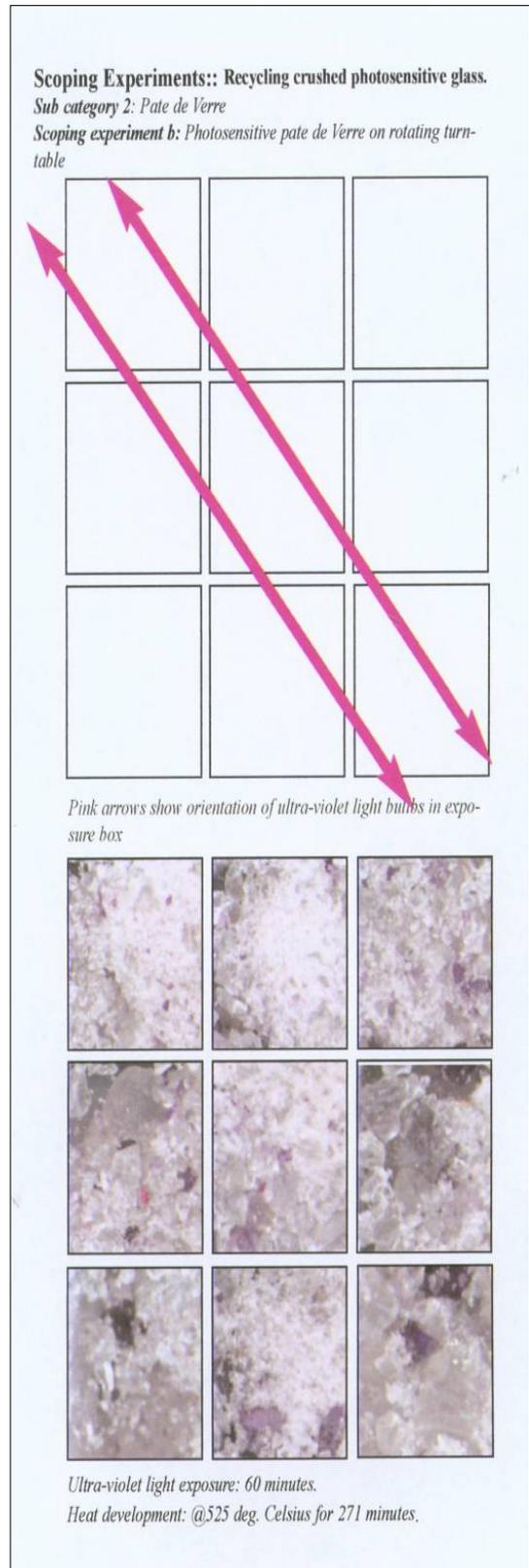
**Figure 26:** Comparisons of sugar granule crystal sizes with crushed white Gaffer Glass #101



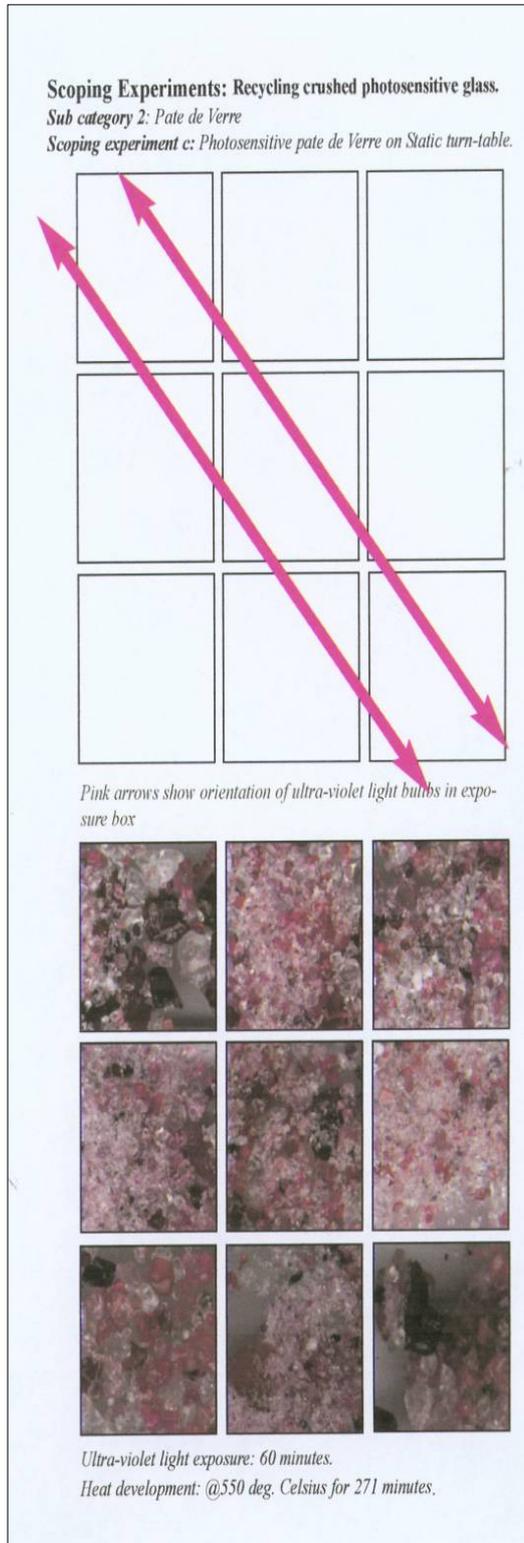
**Figure 27:** Scoping Experiment a



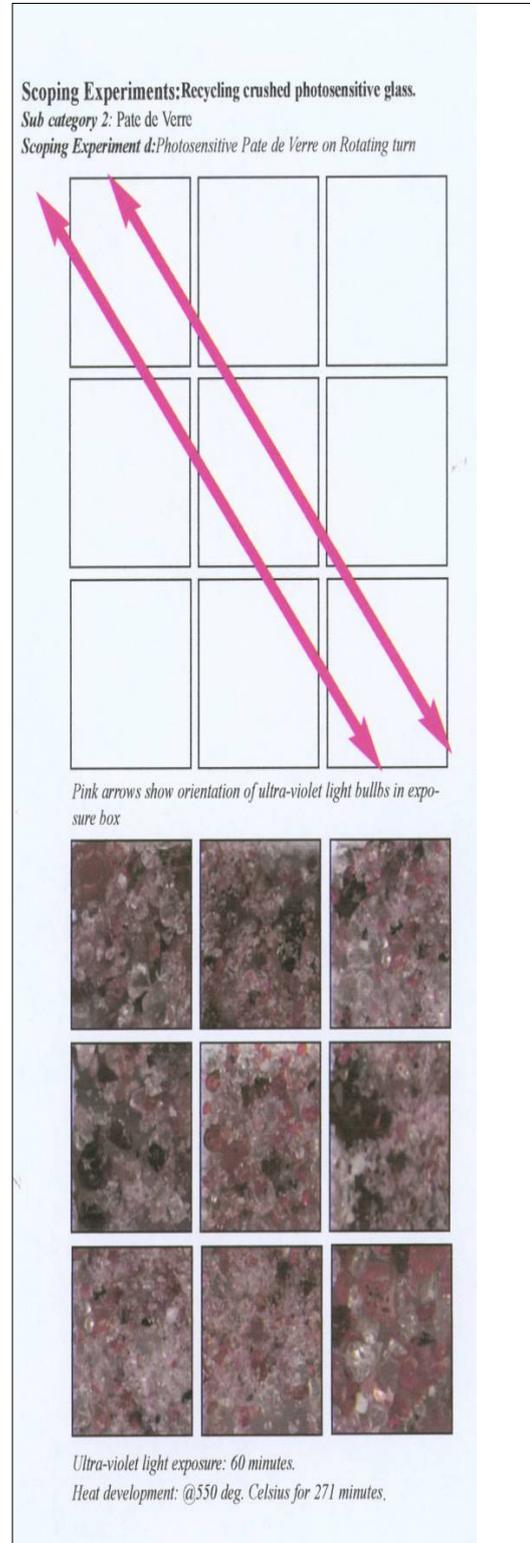
**Figure 28:** Scoping Experiment b



**Figure 29: Scoping Experiment c**



**Figure 30: Scoping Experiment d**



## **Results**

Comparisons between static and rotating turntable results to show relative values were made and it was observed that crushed photosensitive Pate de Verre glass chips off the moyle, ultra violet light exposed for 60 minutes then heat developed at 525, 550, 575 and 600 degrees Celsius for 271 minutes on a non-rotating (static) turn table had darker results at numbers 1, 5 and 9 scanned printouts that those heat developed on a rotating turn table at the same temperatures and time.

## **Conclusion**

The results indicated that experiments involving shorter ultra violet light exposures such as 60 minutes rather than 100, 110 minutes on a (static) non-rotating turn table, then heat developed at a lower temperature such as 525 degrees Celsius would give similar results to the experiment that was heat developed at 550 degrees Celsius and ultra violet light exposed for 60 minutes on a (static) non-rotating turn table. Possible improvements in techniques used were considered in the form of Triaxial and Line blending experiments using photosensitive Pate de Verre for more controlled and informative results.

### **5.2.2i Scoping Experiment I: Pastorelli and Glory-hole experiment**

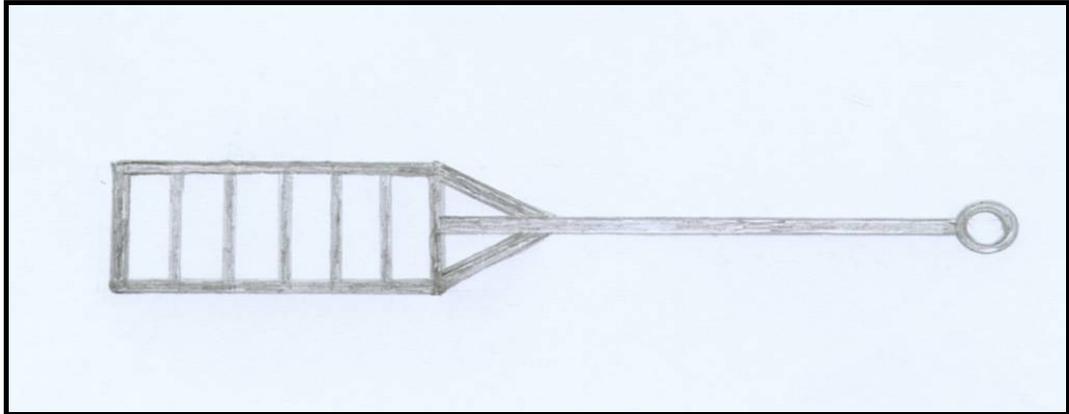
The primary aim of this experiment was to see if assorted raw chips of photosensitive glass would melt on top of a base of crushed and sieved #White Opalescent Gaffer glass so as to be ready for the latent ultra violet light exposure stage. An oblong mould was made to fit onto a pastorelli using Mould Mix #6 to contain the base of crushed variable (d) glass.

## **Results**

### **This scoping experiment was a failure**

There was no colour development at all. The powdered photosensitive glass layer did not received sufficient flaming while exposed to the heat of the Glory-hole in order to '*strike*'. No further experimentation using the mould and pastorelli was made.

**Figure 31:** Diagram of a pastorelli



**Process** details of all the scoping experiments can be seen in Appendix Bii (c) (Chapter Five) scoping experiments Case Study Two.

### **Project aims**

My aims for sub-category 2 were to research and then to experiment how to incorporate photosensitive glass into the traditional technique of making Pate de Verre.

### **Overview of results**

Improvements in the techniques I used were considered and a decision to conduct further scoping experiments in the form of Triaxial and Line blends was made. Unused rods of crushed photosensitive glass were purchased and used with soda-lime furnace glass and an opaque Opal white glass for a more controlled and informative outcome. The triaxial and line-blending experiments are discussed in 5.4.0.Scoping Case Study Four, sub-category 5.4.2. Open face kiln forming.

### **5.3.0. Scoping Case Study Three: [Bead-making/Flameworking] (Hot glass)**

There are three sub-categories that were considered to be suitable for photosensitive glass incorporation as case studies.

Sub-category 5.3.1: Bead-making<sup>58</sup> figure 18(c) page 108.

Sub-category 5.3.2: Button making<sup>59</sup> figure 18(c) page 108.

Sub-category 5.3.3: Core forming<sup>60</sup> (A bead-making process). Figure 18(c) page 108.

#### **Introduction**

This case study describes and discusses the successful and unsuccessful scoping experiments that attempt to incorporate photosensitive glass into the sub-categories of bead-making/flame-working, button making and core-forming (a bead-making process). Flame-working can be defined as the process of melting and manipulating glass using a flame or torch. Today a gas/air or gas/oxygen flame tool called a burner or a bead-making torch is commonly used to make hand-made beads (Bray 2001, 153) taken from the Dictionary of Glass: Materials and Techniques, 2<sup>nd</sup> edition 2001.

#### **General overview of my research into scoping sub category 5.3.1: Bead-making**

Bead-makers/flame-workers use relatively simple equipment to make their beads; a bead-making torch, a bead-making bench, propane or natural gas as fuel, oxygen, some shaping tools, a bead annealing kiln and rods and canes to make the beads. Bead-making/flame working falls into one of the four ancient glass making techniques that are described in Tables 1.0. 1.2 and 1.3 are summarized in Chapter

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<sup>58</sup> Beads were among the first objects made in glass and are thought to have appeared initially in the 3<sup>rd</sup> millennium BC. (Bray 2001, 46).

<sup>59</sup> “A button is officially an object that can be used to fasten garments (Hefti 1999).

<sup>60</sup> A bead making process for making hollow forms, first developed during the Bronze age by the Phoenicians (Klein and Ward 1992, 14).

One. Beads can be made of many materials, but stone and glass beads are particularly immune to destruction and evidence in the archaeological record shows that many survive very well. The popularity of glass and stone beads as a trading item may also be attributed to their imperviousness to temperature, humidity and insect predation. Beads had been used and traded all over the world, for many hundred of years.

### **Stated purpose of the scoping case study**

The purpose of scoping Case Study 5.3.0: Bead-making/Flameworking was to set up a series of systematic scoping experiments with a view to incorporating photosensitive glass into this ancient traditional glass making technique.

Flame-working can be defined as the process of melting and manipulating glass using a flame or torch. Today a gas/air or gas/oxygen flame tool called a burner or a bead-making torch is commonly used to make hand-made beads (Bray 2001, 153).

### **Definition**

Bead-making/flame-working can be defined as a hot glass lamp-working technique that uses an open flame when making glass beads.

### **Overview of Sub-category 5.3.1: Bead-making**

Bead-making is a hot glass technique involving the use of glass canes or glass rods and melting them with a bead-making torch to make beads in a variety of shapes and sizes.

### **Research question (and specific hypothesis) that was applied to sub-category 5.3.1.**

How can photosensitive glass be incorporated into the technique of bead-making?

### **Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of bead-making using a variety of sizes of chips of photosensitive glass were subjected to several random methods that I refer to as scoping experiments.

### **Hypothesis applicable to sub-category 5.3.1. Bead-making**

It is postulated that there is a relationship between the exposure times of the photosensitive glass chips in the base glass of the beads and the controlled ultraviolet light conditions and the development temperatures in an electric kiln under times digital control.

**The objective** was to produce experimental results that would indicate how photosensitive glass could be incorporated into a variety of bead-making techniques.

### **History**

#### **Bead-making**

W.G.N van der Sleen ( 1956, 21) writes that most archaeologists had for long thought that glass was first made in Egypt, where Flinders Petrie discovered glass workshops, lots of very well made beads and other glass objects. A few years ago, however, archeologists found out that glass-making was flourishing over two hundred years earlier under Amenophis I and that the glass-works of Amenophis III could be found at Thebes. This Pharaoh's son was the man who tried to do away with all the old Egyptian gods and called himself Akhenaton, Blessed of the Sun-God. It was at his new capital, Tell el Amarna, that Petrie found the first glass-works that must have been thriving around 1365 BC. Amenophis I died about 1535 BC. It is well known writes van der Sleen (1956, 21) that under these pharaohs Egypt pushed its frontiers farther and farther to the north-east and exchanged presents with the Hittites and other peoples from Babylonia and Assyria. The mother of Akhenaton was said to be a Hittite princess.

Based on an article written by Professor Bezborodov (1965) and a booklet, "*Glass of Old Georgia from the Third Millennium BC*" belonging to Mrs. Ugrelidza and given to van der Sleen at the Archeological Congress of 1965 held in Warsaw. (This booklet was written in the Georgian language and printed in old Georgian characters). Van der Sleen (1956) writes that he had come to the conclusion, based on the facts that glass and beads were made in Russia, just south of the Caucasian Mountains in Georgia, Armenia, Azerbaijan and Tashkent about a thousand years before Tell el Amarna was founded, that the glassworks of Akhenaton were not the beginning of a new period, but the full grown master of this art, developed from trials and errors during eight or ten centuries.

Alexandra Wilson (2003, 2), cites Van der Sleen (1967,17,18) as saying that the bow drill is nearly as old as civilization and ornamental stones like agate could be pierced and strung before the pyramids were built and that in Cambay, India, people had been making carnelian stone beads for the last seven thousand years.

Using a 'small fire' similar to Dudley Gilbertson's description of his 'hot volcano' cone shaped furnace, ancient artisans could make complex beads and core-formed vessels and hollow tubing centuries before the invention of glass blowing.

Beehive furnaces had been recorded in a great many ancient civilizations and furnaces found in Japan are nearly identical to furnaces found in North Africa. These furnaces dominated glassmaking worldwide since before BC. It is well known that glass beads were important mediums of exchange during that period in history, the techniques of working glass are likely to have been spread far and fast across the ancient world (Giberson 1991, 77-78). The Romans also used beehive kilns but made some important changes in their design. The changes they made were a beehive kiln with multiple exhaust vents instead of one or two and access to the crucible was another. The Romans experimented with different tools for extracting the glass from the furnace. This led to the discovery of a primitive blowing pipe and revolutionized the way glass was worked around the world (Lierke 1992, 345-347).

Michelsen R.A and Jennifer Frehling(1995) discuss the historical timeline of Lampworking and Bead-making techniques, tools and furnaces from ancient man through to contemporary man in their co-authored article Until Antonio Neria, an Italian glass maker, published the first book of glassmaking in 1612, the glass trade had been surrounded in secrecy (Jenkins 1997).

### **Identification of a range of experimental issues**

Eye protection was one of the most important issues when doing bead-making experiments. It was essential that correct eye protection is used while making the bead. Kerkvliet (2007, 5) recommends 'rose coloured' didymiums. These bead making glasses are made of two didymiums, Neodymium and Praseodymium, which are both rare earths. These are dichroic lenses that look rose coloured under incandescent light and bluish under fluorescent light and it transmits approximately eighty percent of the visible light, with the exception of the range of the sodium flare which is between 575 to 600 Nm. These lenses also offer good protection against ultraviolet rays. However, these lenses fall short in the filtration of the near to mid infra red spectrum and over time, infra red rays have the potential of harming the eyes. Eye protection protects the eye from developing cataracts after prolonged exposure at the bead-making bench. The larger and hotter the pieces are that you work on, the more infra red rays your expose your eyes to. There is a new lens on the market called AUR-92 and is considered by Kerkvliet (2007) to be better than the regular didymium lenses. Kerkvliet (1995) advises the bead maker to shift her focus from near to far when working with the flame at the bench so as to break the tendency of staring. Problems occur when a bead maker stares at the flame for uninterrupted periods of time. Access to bead-making equipment was important for my collaborator Mrs. Trudy Hardman and in time, for me. Access to an annealing kiln and a flat-bed kiln was essential for the survival of the photosensitive beads. The preparation and storage of photosensitive glass for the experimental procedures was crucial as was adequate safety equipment available in case of accidental burning.

### **Contemporary glass-artists using this sub-category's traditional techniques**

Mark Leib (Western Australia) Cindy Jenkins (USA) Brian Kerkvleit (USA),  
Trudy Hardman (Western Australia).

### **Focus**

The focus of sub-category 5.3.1 Bead-making was on developing a series of unique beads by the incorporation of photosensitive glass into bead making techniques.

### **Scoping experiments for sub category 5.3.1.Bead-making/flameworking (Hot glass)**

Several scoping experimental techniques were attempted to discover whether photosensitive glass could be incorporated into the bead-making process.

I had not at this stage of research learned how to make beads using the gas and oxygen bead-making burner and related equipment therefore it was necessary that collaboration with a colleague who was an experienced bead-maker be established. Having read some of the many articles and books on Lamp working and Bead-making together with my bead-making collaborator, I designed the first scoping experiment as described in sub-category 3.5.1a.

### **Experimental bead-making process in miniature furnace**

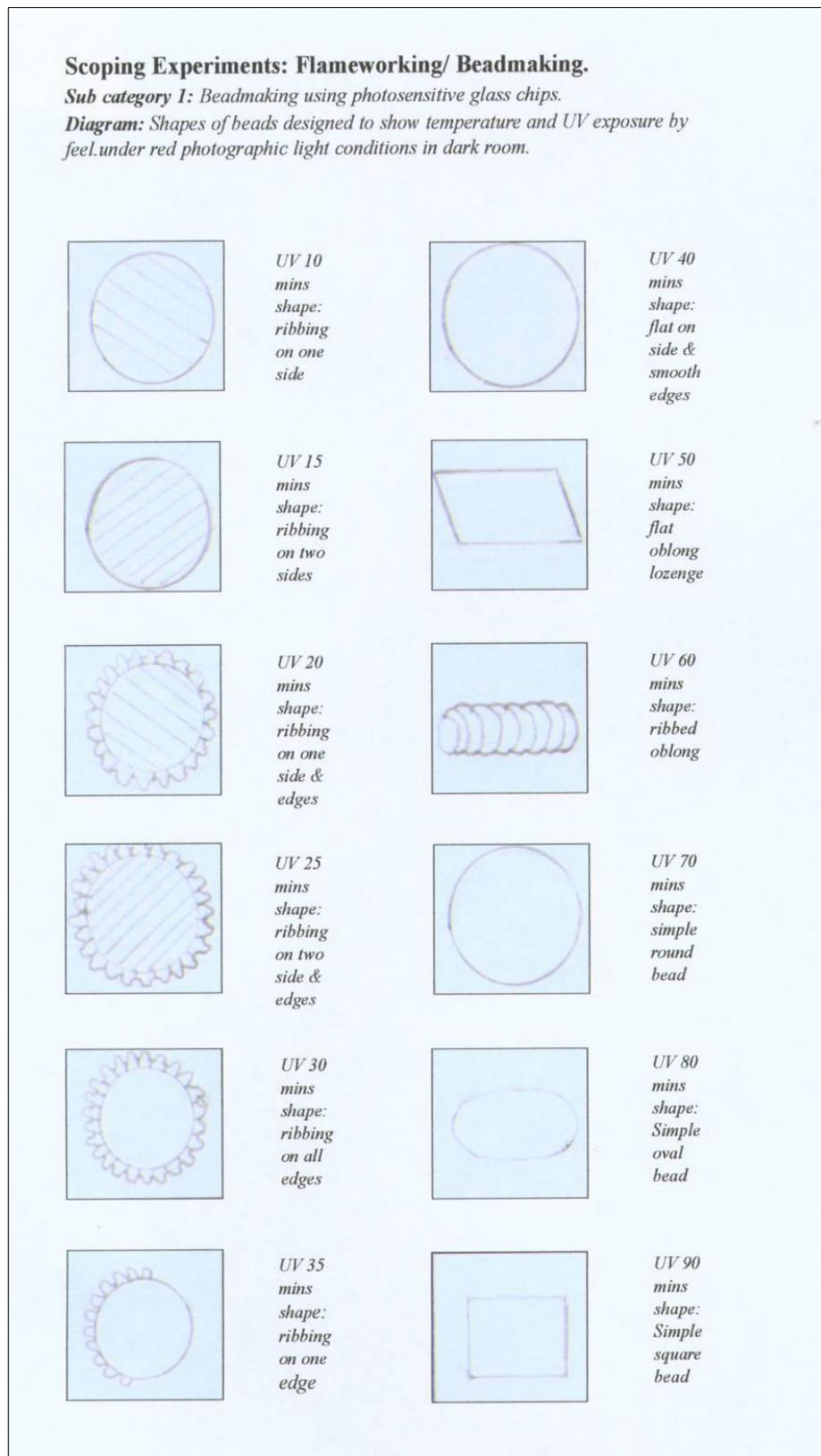
Using a bead-making torch and powdered photosensitive glass and chips of small, medium and large sizes of photosensitive glass together with Spectrum #96 bead-making canes of glass some scoping beads were attempted. In addition to making beads using the oxygen and gas bead-making torch I fired-up my miniature home-made furnace, similar to Dudley Giberson's description of his 'hot volcano' cone shaped furnace to make some additional scoping beads. The photosensitive glass rod was measured, cut up into medallion sized pieces, weighed then crushed into large chips. These chips were then placed into a crucible in the miniature furnace to become molten glass. The molten glass was gathered on a mandrel and shaped into a bead using the heat from the top of the furnace.

## **Result**

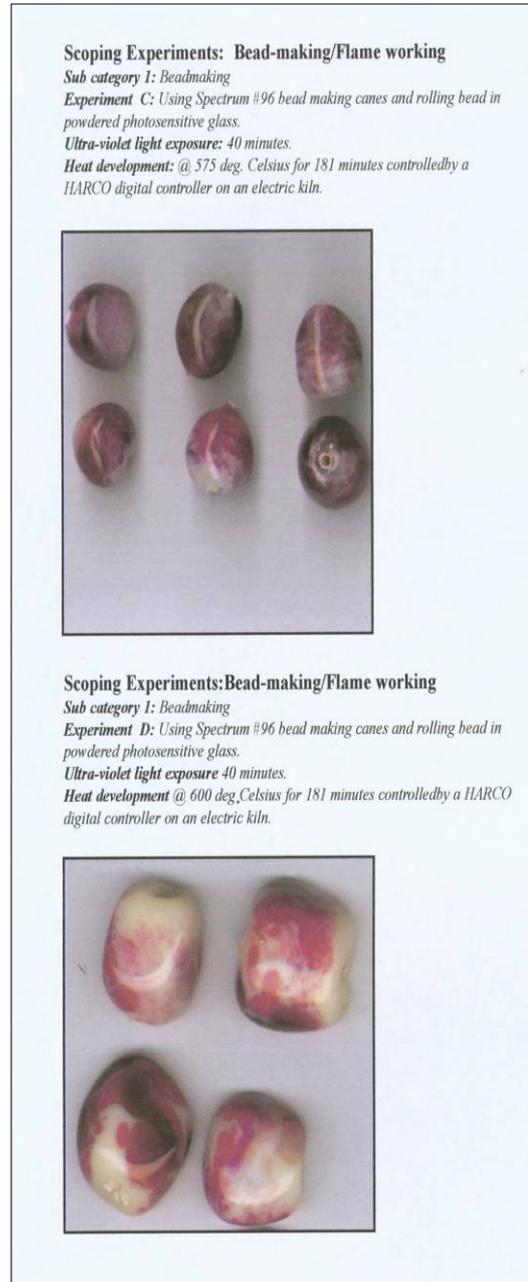
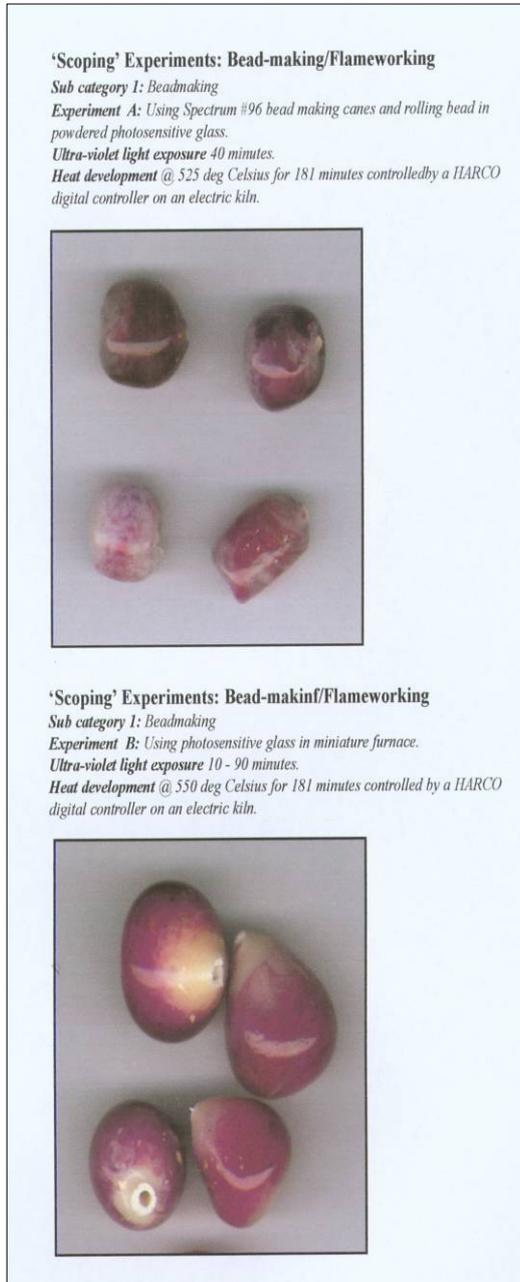
This scoping experiment was unsuccessful. My suspicion is that the high temperature of the photosensitive glass in the crucible of the miniature furnace was responsible for the appearance of the dull dirty red colour of the completed beads. It is postulated that the chemical balance of the ingredients of the photosensitive glass were overheated and could not react to the exposure stage under ultraviolet light nor the timed heat development stage.

It was at this point in time that I considered it important for recognition purposes that each bead needed to have its own shape to correspond with its ultra violet light time exposure. This realization was reached because working in the darkness or under red photographic light it became difficult to remember the ultra violet light exposure times of each bead. Recognizing the ultraviolet light exposure time by feel ensured that fewer errors would be made. Individually shaped beads would also minimize recognition confusion after the heat development stage. The initial time of three hours for heat development at the selected three temperatures was based on extending the length of time exposure had been given to the Stringers and Murrine experiments.

**Figure 32:** Designed shapes for recognizing beads by touch in a darkroom



**Figure 33: Scoping experiments A & B**     **Figure 34: Scoping experiments C & D**



**Figure 33: 5.3.1a. Scoping experiment A (canes)**

Spectrum #96 canes of white opaque glass were used in this experiment because it is compatible with the soda lime photosensitive glass.

## **Results**

The results were disappointing in that the colour of the photosensitive powder coating over the Spectrum#96 Opalescent White beads appeared to have been over exposed. Overexposure to ultraviolet light is suspected because of the dull pinkish-red colour of all the beads.

## **Conclusion**

This over exposure could have occurred either during the photosensitive glass powder coating stage causing by the latent ultraviolet light in the room and/ or by the heat of the bead-making torch at the bench.

### **Figure 33:** 5.3.1b. Scoping experiment B (in miniature furnace)

## **Results**

The results were disappointing as were the results of the photosensitive powder coated glass beads. The overall dull dark-pink colour appeared to be more even than the powder coated beads due to the '*dipping*' of the bead into the molten glass of the crucible at the gathering stage. There was no gradation of colour according to the length of time the beads were exposed at the ultra violet light stage. All ten beads were the same colour.

## **Conclusion**

It is suspected that the molten photosensitive glass may have become '*over cooked*' in the crucible. I noticed that the first few beads dipped into the molten photosensitive glass within the first twenty minutes appeared to be less '*cooked*' in appearance than the beads made after half and hour or longer. I suspect that photosensitive glass may have a time-frame of workability before the material properties are altered. This assumption needs further exploration and experimentation.

### **Figure 34:** 5.3.1c. Scoping experiment C (canes)

As in experiment A, the results were similarly disappointing. The higher temperature resulted in the beads becoming light pink-reds, and dark, dusty-reds.

I suspect that the powdered photosensitive glass became exposed to the latent ultraviolet light present in the workshop/studio during the melting stage onto the #96 Spectrum Opalescent White bead or that by powdering the photosensitive glass altered the material properties.

When the bead being made was sufficiently hot and molten enough it was rolled in the photosensitive powder then returned to the torch to melt the powder into the Opalescent White bead on the mandrel. It was at this point in time that I considered it important for recognition purposes that each bead needed to have its own shape to correspond with its ultra violet light time exposure. This realization was reached because working in the darkness or under red photographic light it became difficult to remember the ultra violet light exposure times of each bead. Recognizing the ultraviolet light exposure time by feel ensured that fewer errors would be made. Individually shaped beads would also minimize recognition confusion after the heat development stage. The initial time of three hours for heat development at the selected three temperatures was based on extending the length of time exposure had been given to the Stringers and Murrine experiments.

**Figure 34:** 5.3.1d. Scoping experiment D (canes)

Experiment D was subjected to the same processes as experiments A and C. The only difference was the heat development temperature of 600 degrees Celsius for the same time in the electric kiln.

**Results**

The colour red was deeper and clearer as was expected due to the higher heat development temperature.

**Conclusions**

I concluded that photosensitive glass powder coated beads should be made in a darkened workshop area to minimize the ultra violet light from the room and bead-making torch that a may have affected the bead during the making process. The length of time and high temperature during heat development is also suspected of having had an effect on the final colour of the photosensitive powder

coated glass bead. I suggest that to overcome the problems associated with the making of photosensitive powder coated beads, heat development of these beads at lower temperature ranges such as 495 and 505 degrees Celsius would give more positive results. Controlled heat development for shorter lengths of time is believed to be necessary to achieve a wider colour range. If this solution does not work, it is suspected that powdering of the photosensitive glass may be the problem in that the chemical particles in the glass body material may not give the same results as larger pieces of photosensitive glass.

**Figure 35:** 5.3.1e. Scoping experiment E (canes)

### **Results**

The results were varied and some beads showed signs of a mauve colour within the clear red to dark red colour. I suspect that the light clear red colour was due to a few medium sized chips that melted onto the bead.

### **Conclusion**

I am of the opinion that this scoping experiment was successful because it showed that colour development other than a clear red was possible. Colour development of blue-mauves, mauves to purples together with a variety of red colours was seen. This colour development I suspect is due to the ultraviolet light exposure time, the lower temperature and the length of time for the heat development state and may be factors responsible for the appearance of a mauve colour with the clear red colour.

**Figure 35:** 5.3.1f. Scoping experiment F (canes)

### **Results**

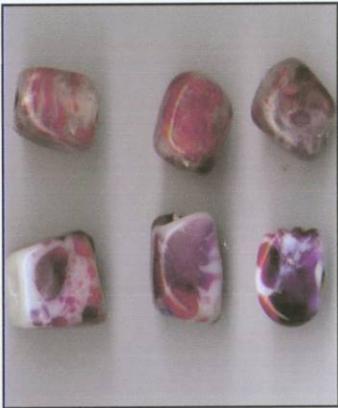
The results were varied and some beads showed patches of a mauve and purple colours within the clear reds and dark red colours of the 'square' shape bead. Development signs of small blue-mauve areas could be seen in some beads. I suspect that the lighter clear red colours are due to few medium sized chips of photosensitive glass being melted into the bead.

**Figure 35:** Scoping experiments E & F    **Figure 36:** Scoping experiments G & H

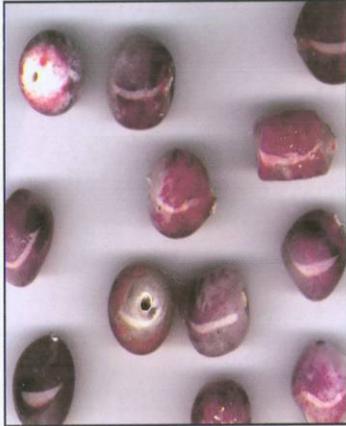
**Scoping Experiments: Bead-making/Flame working**  
**Sub category 1: Beadmaking**  
*Experiment E: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
*Ultra-violet light exposure: 40 minutes.*  
*Heat development: @ 525 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.*



**Scoping Experiments: Bead-making/ Flame working**  
**Sub category 1: Beadmaking**  
*Experiment F: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
*Ultra-violet light exposure: 40 minutes.*  
*Heat development: @ 550 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.*



**Scoping Experiments: Bead-making/ Flame working**  
**Sub category 1: Beadmaking**  
*Experiment G: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
*Ultra-violet light exposure: 40 minutes.*  
*Heat development: @ 575 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.*



**Scoping Experiments: Bead-making/Flame working**  
**Sub category 1: Beadmaking**  
*Experiment H: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
*Ultra-violet light exposure: 40 minutes.*  
*Heat development: @ 600 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.*



## Conclusion

The experiment appears to have been successful in showing that colour development of blue-mauves, mauves to purples together with a variety of red colours is possible. This colour development is believed to be due to the following factors; the thickness of the chip of photosensitive glass together with

the shorter time in getting them to become incorporated within the Spectrum #96 glass bead as well as the ultra violet light exposure time, medium hot temperature and the length of time for heat development.

**Figure 42: 5.3.1g. Scoping experiment G (canes)**

The beads in this scoping experiment were made using the process as described in scoping experiment B. The beads were removed from the light box after being exposed to ultraviolet light for 40 minutes. They were then heat developed in a HARCO controlled electric kiln at a temperature of 575 degrees Celsius for 181 minutes (3 hours).

**Results**

The colours of these beads were similar to those on the colours of the miniature furnace made beads. They showed irregular patches of thin dull-red colour together with a very dark red colour.

**Conclusion**

This scoping experiment was unsuccessful. I conclude that the high temperature of 575 degrees Celsius at the heat development stage is the cause of the dull red and dark colours.

**Figure 42: 5.3.1h. Scoping experiment H (canes)**

The beads, made as described in scoping experiment B were removed from the light box after 40 minutes ultraviolet light exposure after which they were heat developed in a HARCO controlled electric kiln at a temperature of 600 degrees Celsius for 181 minutes (3 hours).

**Results**

The colours on these beads ranged from pink (control bead with no ultraviolet light exposure) to medium red to dark, dark red. They showed irregular patches of a dull red colour within the medium reds and dark, dark reds.

**Conclusion**

A temperature of 600 degrees Celsius at the heat development phase is suspected of being the cause of the patchy dull red to dark, dark red colours.

**Figure 37: 5.3.1i. Scoping experiments I & J (miniature furnace)**

**Scoping Experiments: Bead-making/Flame working**

*Sub category 1: Beadmaking*

*Scoping Experiment I: Using photosensitive glass in miniature furnace.*

*Ultra-violet light exposure: 60 - 10 -40 minutes.*

*Heat development: @ 575 deg.Celsius for 271 minutes controlled by a HARCO digital controller on an electric kiln.*



*Control  
Bead  
No UV  
expo-  
sure.*

*Bead A.  
UV  
exposure  
Top 60  
Mid 10  
Base 40  
mins.*

*Bead B.  
UV  
exposure  
Top 60  
Mid 10  
Base 40  
mins.*

*Bead C  
UV  
exposure  
Top 60  
Mid 10  
Base40  
mins.*

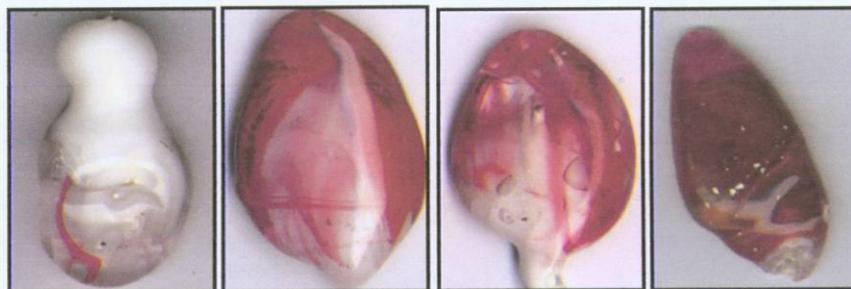
**Scoping Experiments: Bead-making/Flame working**

*Sub category 1: Beadmaking*

*Scoping Experiment J: Using photosensitive glass in miniature furnace.*

*Ultra-violet light exposure 100 - 105 minutes.*

*Heat development @ 550 deg.Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.*



*Control  
Bead  
No UV  
exposure*

*UV  
exposure  
100  
mins.*

*UV  
exposure  
105  
mins.*

*UV  
exposure  
110  
mins.*

**Figure 37:** 5.3.li. Scoping experiment I (in miniature furnace)

A set of four beads was made using the heat from the top of the miniature furnace as described in scoping experiment B. Because photosensitive glass could become '*over cooked*' as in Scoping experiment B, I worked as quickly as it was possible to test the time frame factor. After annealing the beads were masked to exclude areas from ultra violet light exposure in the light box. They were then heat developed @ 575 degrees Celsius for 271 minutes in a HARCO controlled electric kiln.

**Results**

The three ultra violet light exposed photosensitive beads A, B & C appear to have a '*burnt*' dull-red to dark brownish red colour. The control bead remained pinkish cream because it had not been exposed to any ultraviolet light.

The band of light dull-pink in the middle of each bead is where the ultra violet light was excluded after ten minutes of exposure. There is no sign of any difference between the base of the bead @ 40 minutes exposure and the top of the bead @ 60 minutes exposure.

**Conclusion**

The colours of the three beads indicate that the photosensitive glass was '*over cooked*' in the furnace. I suggest that the length of time taken for heat development may have been too long and the temperature too high.

Melting photosensitive glass rod chips in a crucible of the miniature furnace for gathering purposes may not produce results similar to melting chips of photosensitive glass directly into the body of the bead using a bead-making torch. Photosensitive glass melted down in a furnace crucible may have its chemical metallic properties altered.

**Figure 43:**5.3.1j. Scoping experiment J (miniature furnace).

A set of beads was made using the heat from the top of the miniature furnace as described in scoping experiment B. After annealing the beads, they were exposed to ultraviolet light for 100, 10 and 110 minutes in the light box then heat

developed @550 degrees Celsius for 181 minutes in a HARCO controlled electric kiln.

### **Results**

Bead A and bead B have developed a clear red colour and bead C has a dark red colour

### **Conclusion**

I assume that 181 minutes of heat development time is responsible for the clear reds of bead A and bead B. I assume that the dark red colour of bead C is due to either the ultraviolet light exposure being too long or that the molten photosensitive glass in the crucible had reached that '*cooked*' time factor.

### **Figure 38: 5.3.1k. Scoping experiment K (in miniature furnace)**

A set of twelve beads was made using the heat from the top of the miniature furnace as described in scoping experiment B. The beads were annealed and then exposed to ultra violet light for five minute intervals from ten to ninety minutes in the light box then heat developed @ 550 degrees Celsius for 181 minutes in a HARCO controlled electric kiln.

### **Results**

The results were very disappointing that that all the beads appear to have a "*cooked*" or '*burnt*' colour.

### **Conclusion**

I assume that the problem lies in the molten photosensitive glass in a crucible for gathering photosensitive glass onto a mandrel. The properties of molten photosensitive glass need to be examined scientifically as I suspect that the chemical nature of the glass has been altered by the melting down of the glass in a crucible.

**Figure 38:** 5.3.1k Scoping experiment K (miniature furnace)

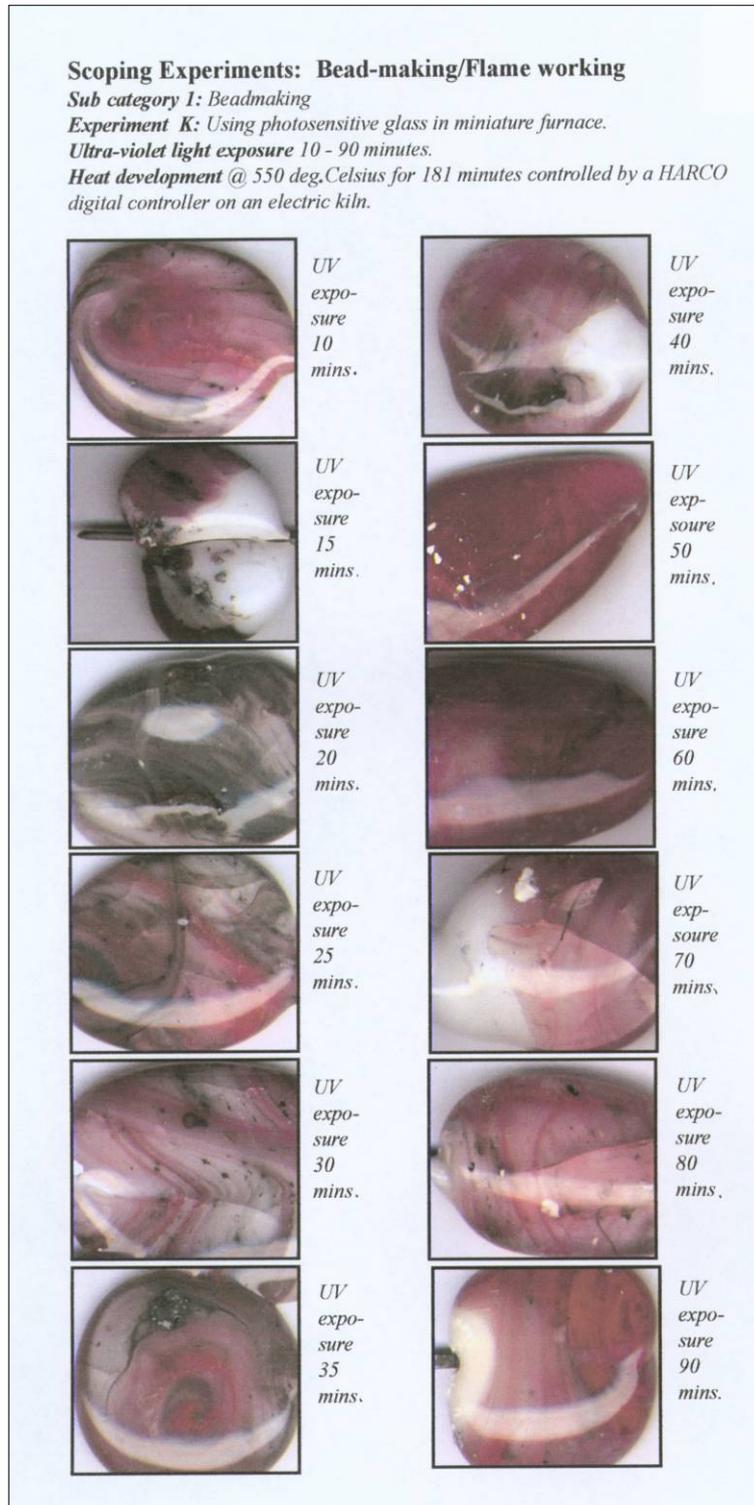
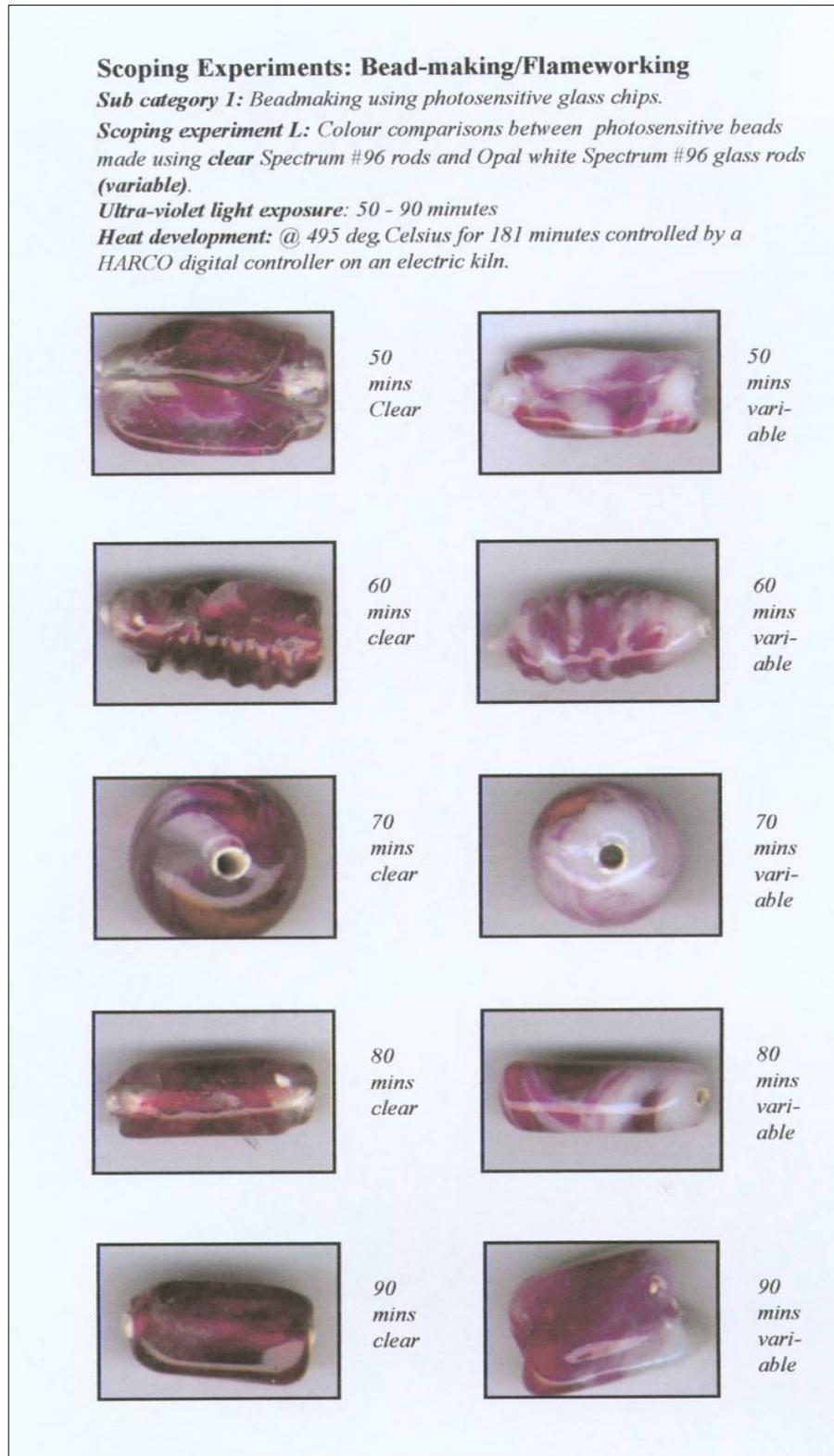


Figure 39:5.3.11. Scoping experiment L Colour comparisons (canes)



**Figure 39:** 5.3.11. Scoping experiment L Colour comparisons (canes)

A set of ten photosensitive glass beads was made using the bead-making torch. Five of the beads were made using a cane of Spectrum# Opalescent White beneath the coating of photosensitive glass and the following five beads were made using a cane of clear Spectrum #96. The purpose of this scoping experiment L was to compare the differences in the colours produced by using the different Spectrum #96 canes as bases. The beads were annealed and then exposed to ultra violet light for five minutes intervals starting at 50 minutes and ending at 90 minutes in the light box then heat developed @ 495 degrees Celsius for 181 minutes in a HARCO controlled electric kiln.

**Results and conclusion**

The results were interesting in that the beads made with the clear Spectrum #96 differed by being darker in colour from the five beads made using the White Opalescent Spectrum #96 (the variable).

**Case Study project aims.**

The project aims of Case Study Three were to incorporate photosensitive glass into the glass making techniques of all the sub-categories through a scoping experimental approach.

**Process (standard application) and technical skills**

The technical process for making the scoping bead experiments can be seen in Appendix Biii(a) (Chapter Five) scoping Case Study Three: Bead-making.

**Issues**

Physical Issues

Annealing - Graham Stone (2000) advised that beads should be annealed in a bead-making electric anneal kiln directly after being made. The storage of the photosensitive glass beads while still on their rods was an issue. This issue was dealt with by plunging hot bead still on its rod into a crockpot containing hot vermiculite while waiting to transfer a group of made beads in the annealing kiln

at the end of the bead-making session. When the beads had been annealed I placed the beads, still on their rods into light proof cardboard cylinders and stored them in black photographic plastic bags until I was able to expose them under ultraviolet light. This activity took place under safe red photographic light set up in the studio.

#### Theoretical Issues

The theoretical issue of bias was similar to those in all the case studies and their sub-categories.

### **Sub category 5.3.2. Button making**

#### **Introduction**

Button making is a branch of bead making. The button is used as an ornament as well as in a functional way of fastening clothing.

#### **Definition of a button**

*“A button is officially an object that can be used to fasten garments, either a shank ( usually a loop) on the back used to sew the button to the clothing, or with holes in the center to allow thread to pass through the body of the button”* Diana, L. Hefti (1999).

#### **Research question (and specific hypothesis) that was applied to sub-category 5.3.2: Button making**

What and how many methods can I apply to incorporate photosensitive glass into the traditional technique of button making?

#### **Solution to the research problem**

By applying the experimental form of the scientific method, my random scoping experimental techniques of incorporating crushed, raw photosensitive glass in the button making techniques.

### **Hypothesis applicable to sub-category 5.3.2: Button making**

It is postulated that there is a relationship between the exposure times of the photosensitive glass chips in the base glass of the buttons and the controlled ultraviolet light conditions and the development temperatures in an electric kiln under timed digital control.

### **Objectives**

The objectives were to produce experimental results that would indicate how photosensitive glass could be incorporated into glass button making.

### **History**

Sandra Scham (2008) states that “*Functional buttons, have been found at the site of Gobekli Tepe in south eastern Turkey, dates at 10,500 BC*”. Functional buttons made from stone were discovered in the Indus Valley Civilization during its Kot Dijii phase (circa 2800-2600 BC). Hefti (1999) writes that clothing was fastened by ties or pins and used mainly as ornaments rather than fasteners, after that buttons and toggles gradually came into use. This evidence was gathered from ancient burial sites that contained button-like objects. It was discovered that during Early and Middle Bronze Ages in China (circa 2000-1500 BC) and Ancient Rome, large buttons were mainly used to fasten cloaks or capes. During the 13<sup>th</sup> Century, buttons came to be mainly used as a form of decoration. Buttons on garments were not used as a method for closing or fastening garments until the middle the 16<sup>th</sup> Century, before this time, lacing up or hooks were used to keep garments closed. The size of buttons during this time period was small, but later during the next century they became larger and very ornate, often using precious metals and jewels. Most buttons were worn by men during the 17<sup>th</sup> and 18<sup>th</sup> Century. Lynn White, (1962, 486-500) writes that functional buttons with buttonholes for fastening or closing clothing appeared first in Germany in the 13<sup>th</sup> Century becoming widespread with the rise of tighter fitting garments in 13<sup>th</sup> and 14<sup>th</sup> Century Europe. During the 18<sup>th</sup> Century, buttons continued to become larger with more elaborate design. The button-making industry reached a high standard

fashion statement during the period from 1830-1850. This period become known as the Golden Age of Button making. Women customers became the main consumers of “novelty” buttons from 1860 onwards. Claire Stella Davies (1976) claims that during the reign of Elizabeth I, a new industry called button making was recorded in 1574. Davies (1976) points out that buttons are mentioned in Shakespeare’s King Lear” in 1604.

### **Contemporary glass artists using this traditional button making technique**

Trudy Hardman (WA). Marie-Christine Mahe (USA).

#### **Focus**

The focus was on developing a range of buttons that would appear unique in the art glass button making area. It was anticipated that this would be possible when photosensitive glass was incorporated into the flame working button making techniques.

#### **Process (standard application) and technical skills required**

The technical skills required to make buttons are very similar to the technical skills used in bead making (described in sub-category 5.3.1.of this case study). The process for the scoping button-making experiments can be seen in Appendix Biii(b) (Chapter Five) scoping Case Study Three.

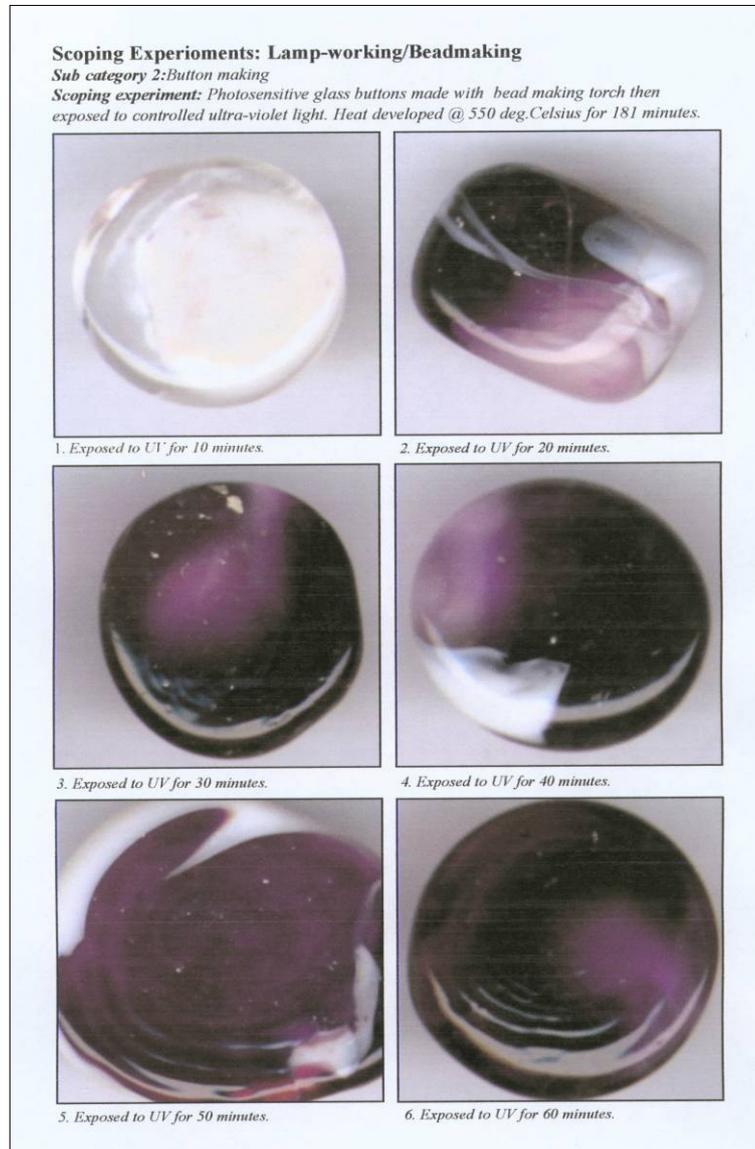
#### **Identification of a range of experimental issues**

Access to bead-making equipment to carry out the scoping button making experiments was an issue and another issue was having access to an annealing kiln, a flat bed kiln and knowing that there was adequate safety equipment close at hand in case of an accidental health or fire emergency.

#### **Scoping experiments**

Two scoping experiments were carried out in button making.

**Figure 40:** 5.3.2. Scoping experiment for six photosensitive glass buttons



**Figure 40:** 5.3.2a. Experiment 1: Six photosensitive buttons

Six buttons were made by my collaborating colleague Trudy Hardman. Spectrum #96 opal white glass cane and large photosensitive glass chips were used. A special style of double mandrel was made for these buttons so as to give them two holes in the centre.

## **Results**

The colour results were narrow in range. The button exposed to ultra violet light for only ten minutes was the exception. It was pale white-pink unlike the buttons exposed from 20 minutes to 60 minutes. These five buttons ranged from medium mauves at 20 minutes, medium purple at 30 minutes, pale mauves and purple at 40 minutes to red-purple at 50 and 60 minutes. The special double holes made using the double mandrel in all the buttons had by this time disappeared due to the heat development of the buttons.

## **Conclusion**

I believe that there is potential in designing a range of firing schedules to suit the making of buttons. This firing range needs to deal with the heat development temperatures so that optimum colours can be achieved as well as keeping the especially made holes for sewing the button onto the garment.

### **5.3.2b. Scoping Experiment 2**

Using Spectrum#96 opalescent white glass canes, ten buttons were made using the Bead-making torch.

## **Results**

The results showed no difference in colour from 10 to 30 minutes for the two temperatures and the two different lengths of exposure times. All ten buttons were of a similar red colour. A lighter red can be seen where the photosensitive glass was thin and dark red where the chip had been thicker. The special double holes in all the button had by this time disappeared.

## **Conclusion**

This scoping experiment was unsuccessful.

### **Project aims: sub-category 5.3.2 button making.**

The aims for this button making sub-category were to experiment with as many ways as it was possible to incorporate photosensitive glass into the technique of making a button. Refer to bead making experiments for colour guidance using a variety of ultra violet light exposure times and different heat development

temperatures and times in Appendix Biii(b) (Chapter Five), scoping Case Study Three.

### **Issues**

Physical Issues were similar to those experienced in Bead-making.

The theoretical issues were similar to those of the other case studies concerning bias.

### **Selecting my experimental variables**

To predict an outcome in any experimental research, some variables are controlled and some are manipulated. Therefore it is necessary to define the basic variables then only change one variable at a time in an experiment. The dependent variable is the phenomenon that appears, disappears or changes as the independent variable is applied (Allison, O'Sullivan and Owen 1996, 7-29)

### **Measuring my Independent Variable and my Dependent Variable**

The dependent variable was the intensity of the colours of the developed photosensitive glass in the button scoping experiments. The independent variables were the exposure times of the photosensitive glass experiments to ultraviolet light, the heat development temperatures that the experiments were fired at in the electric kiln and the length or rate of the time that the experiments were held (soaked) at a designated temperature in the digitally controlled electric kiln, the type and amount of opaque glass that was added to the photosensitive glass experiments and finally the thickness of the photosensitive glass in the experiment.

To start with, clear canes of #Spectrum 96 glass were used as a base for the button-making scoping experiments – this was the basic control and the photosensitive glass chips that were incorporated into the clear glass of the button while it was being made was the dependent variable. A cane of #Spectrum96 Opalescent white was the alternative bead-making base that was used instead of

the #Spectrum 96 clear cane and the reaction resulting from being exposed to ultraviolet light and heat development temperatures between the dependent variable (photosensitive glass chips) and the two different types of canes, was the independent variable that produced a slightly different colour outcome in the buttons.

### **5.3.3: Sub-category 3: Rod and core forming<sup>61</sup>** (A bead-making process)

#### **Introduction**

This technique is related to one of the methods of bead-making and is the process of coating a form on the end of a rod with molten glass to make a vessel. A rim, handles and a foot may be applied to the vessel. The rod used in this procedure is called a mandrel.<sup>62</sup>

#### **Research question (and specific hypothesis) that was applied to subcategory 3.3.3: Rod and core forming**

What methods can I use to incorporate photosensitive glass into the traditional technique of core forming?

#### **Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of crushing the raw photosensitive glass were subjected to several random methods that I refer to as scoping experiments.

#### **Objectives**

My objectives were to reproduce core formed glassware in the ancient manner as well as incorporating photosensitive glass into this difficult technique for purely decorative purposes.

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<sup>61</sup> A bead-making process for making hollow forms first developed during the Bronze Age by the Phoenicians (Klein and Ward 1992, 14).

<sup>62</sup> A mandrel is a metal rod made to hold the core. Stainless steel rods of varying diameter and length are preferred by bead-making/flameworking artists.

## **History**

Core forming was one of the oldest techniques to form hollow glass-ware before the invention of blowing and dates from about the middle of the second millennium AD. It is not precisely known but it is thought that the origin of core-forming may have been developed in the Kingdom of Mitanni, a Hurrian state in northern Mesopotamia and northern Syria during the mid-second millennium.

In 1894, Sir Flinders Petrie excavated factories in Egypt that were producing core vessels. These factories were established after the Hyksos were expelled from Egypt in the middle of the 16<sup>th</sup> century by the rulers of the New Kingdom, Thutmose III or later on by Rameses II (Klein and Lloyd 1992, 14).

*“Core formed vessels. A method of making hollow forms, which is said to have been developed in ancient Egypt about 1500 years before glassblowing was discovered. They eventually become very sophisticated, beautifully trailed and combed, copying various Hellenistic forms”* (Bray, 2001, 85). Purely rod formed objects, such as a group of head pendants normally ascribed to Phoenician craftsmen, were made in much the same manner except that they dispensed with a core and were formed directly on a metal rod. Presumably the rod was covered with a very thin layer of some material which acted as a separating agent (Klein and Ward 1992, 10-13).

## **Contemporary Glass Artists using the traditional techniques of this sub-category**

Paul T. Nicholson (UK), Iwao Matsushima (Japan), Mark Taylor and David Hill (UK) (2006).

## **Focus of sub-category**

The focus on this sub-category was on two aspects. First, how to incorporate photosensitive glass into the difficult and ancient technique of core-forming and second to research and experiment with the ingredients of the materials that traditionally make up the core with the intent of using a more modern material for the core.

**Process** (Standard applications) and technical skills required for making the core-formed vessels can be seen in Appendix Biii(c) (Chapter Five) scoping Case Study Three.

### **Technical issues**

Technical issues regarding the making of a core vessel can be divided into two major sections:

- Making a core
- Covering the core with glass to make a hollow vessel.

### **Theories**

There are several theories about core making methods used by ancient glassworkers for applying glass over the core. Schuler (1962) believes that the core was dipped into a suspension of powdered glass in water. Stern and Schlick-Nolte (1994) suggest that the core was coated with crushed and powdered glass then melted. Gudenrath (1991) claims that the core was dipped directly into a pot of molten glass. Labino (1966) believes that molten glass was trailed around the core. Labino worked using a side entrance to his furnace, trailing the glass onto the core inside the furnace, immediately above the crucible<sup>63</sup>. Mark Taylor and David Hill (2006) suggest that the core mixture be made up by mixing clay with vegetal remains and sand in the correct ratios and shaping, drying and firing the

---

<sup>63</sup> *“The glassworker models a core with a mixture of clay and horse dung and applies it to the end of a non-hollowed metal rod. The core is immersed in a crucible of incandescent glass, which adheres around the core. The small size of the objects allowed the core to be immersed even in very small crucibles. Then the glassworker decorates the outside wall with different coloured glass filaments, and if desired, then moving them with a tool to form festoons. Handles may be applied. This reconstruction of the process used is based on recent analytical observations on archaeological glass and experiments in glassworks and is accepted by the most eminent glass archaeology scholars. So the hypotheses that the core was made of sand and that the body of the vase was produced only with a filament wrapped around the core, have been rejected (Taylor and Hill 2006).*

core to about 1000 degrees Celsius before starting to make the vessel. Taylor and Hill (2006) claim that by following this technique the honeycombed fired core will be strong enough to withstand the glass-working stage, but weak enough to crush as the glass shrinks around it on cooling, and should not break the glass vessel. The addition of sand is not necessary but is does held to reduce the shrinkage of the core on drying. After experimenting with several combinations of ingredients Taylor and Hill (2006) found that a mixture of clay and finely chopped and sieved straw, with sand as an optional was the most suitable for their technique. The ingredients are measured by volume water added then mixed up into a sticky mass. Taylor and Hill (2006) argue that this method is similar to the materials and method used by Gudenrath (1991).

### **Identification of a range of experimental issues**

My experimental issues were similar to the issues experienced in the sub-categories of bead-making and button making. In addition I needed to find out

Where I could learn to make core formed objects and failing that where would I find a collaborator to make core formed photosensitive glass objects?

How long could I store the photosensitive glass core formed vessels before exposing them to ultraviolet light then heat developing them?

What annealing requirements were there for photosensitive glass core formed objects?

### **Core making scoping experiments.**

The material forming the core has been the subject of research and experimentation (Bimson and Werner 1969, 262-266) Core material from 14<sup>th</sup> century Egypt was found by Bimson and Werner (1969,121-122) in their analyses of 62 samples to be a mixture of burnt out organic matter and '*a flaky mass of dark brown material*'. Some of these cores appeared to have been coated with a powdered limestone and clay slip. This outer coating of slip way have functioned as a releasing agent for removing the core.

## **Conclusion**

My collaborating colleague, an experienced bead-maker (see figure 9a ) found that the application of fine glass trails to the core by melting the tip of a pre-formed, thin rod and attaching it to the vessel body then turning the vessel to wind the rod around it very difficult to coat the entire core. Photosensitive glass incorporation had not at this stage been attempted. It was at this stage that a miniature furnace to provide a supply of molten glass to cover the core became advantageous. My original intention had been to cover the core with molten glass from the miniature furnace then roll the hot core covered glass over pre-heated photosensitive glass chips before returning the core to the bead-making torch for flashing. Instead I made a core using Spectrum #96 Opalescent White cane for the base covering of the core of the bead using the Hot-head burner on the bench. I then dipped the three covered cores into the crucible of the miniature furnace which contained molten photosensitive glass chips. The photosensitive cores were then annealed with the mandrels still attached. After the three photosensitive glass covered cores had been annealed they were exposed to ultraviolet light on a rotating wheel in the light box. The mandrels were removed under safe red light conditions, then the core was removed and the inside of the three vessels were cleaned out before placing them in a digitally controlled electric kiln for heat development.

## **Project aims for scoping Case Study Three, sub-category 5.3 3. Core forming.**

My aims for this core forming sub-category of scoping Case Study Three were to experiment with as many known ways as possible in making the actual cores and then as many ways as possible applying the photosensitive glass to the core before exposing the core formed objects to ultraviolet light before heat developing them in an electric kiln using a digital controller.

## **Issues**

The main physical issue I encountered was the learning and then practicing how to make a core formed vessel in the short time that I had time for to do my research.

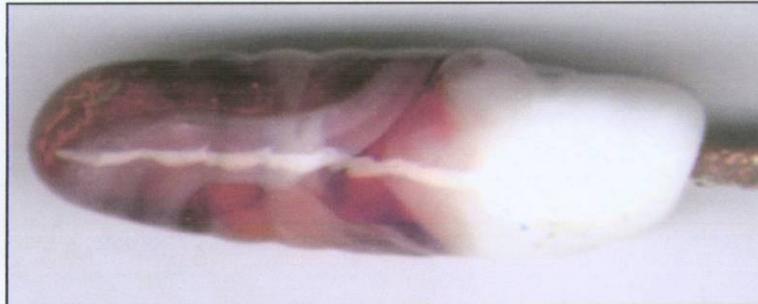
**Figure 41:5.3.3.** Three core formed photosensitive glass scoping experiments

**Scoping Experiments: Flame-working (Hot-glass)**

*Sub category 3: Corformed vessels*

**Scoping Experiment:** *Three mini furnace made Photosensitive Core Vessels*

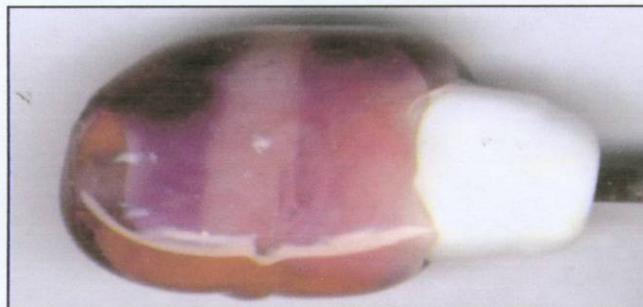
*Three photosensitive glass core vessels were made using the crucible in the miniature furnace. Controlled exposure to ultra-violet light was followed by controlled heat developed in three different electric kilns for the same length of time under digitally controlled conditions.*



*Kiln No: G1. Heat developed @ 550 deg Celsius for 181 minutes  
Exposed to ultra-violet light for 40 minutes at base of core vessel, 10  
minutes at middle and 60 minutes at tip of vessel.*



*Kiln No: G2. Heat developed @ 550 deg Celsius for 181 minutes.  
Exposed to ultra-violet light for 40 minutes at base of core vessel, 10  
minutes at middle of vessel and 60 minutes at tip of vessel.*



*Kiln No: G3. Heat developed @ 550 deg Celsius for 181 minutes  
Exposed to ultra-violet light for 40 minutes at base of vessel, 10 mins  
at middle of vessel and 60 minutes at tip of core vessel.*

#### **5.4.0. Scoping Case study Four: Kiln casting/Kiln formed glass [Warm-glass]**

There are two sub-categories that are suitable for a potential scoping case study.

Sub-category 5.4.1: Kiln casting/slumping<sup>64</sup> glass, figure 18(d) page 109.

Sub-category 5.4.2: Simple open-face casting – using a triaxial blended system for Pate de Verre<sup>65</sup>, figure 18(d) page 109.

#### **Introduction**

This case study discusses two traditional warm glass techniques, kiln casting/ kiln forming glass and simple open face casting. These techniques require an understanding of warm glass principles. In general, kiln casting or kiln forming refers to the melting of glass inside a kiln usually inside a mould.

#### **Overview of the two sub-categories in scoping Case Study Four: 5.4.1.Sub-category 1: Kiln casting/Kiln slumping glass**

Kiln casting is similar but not identical to kiln forming<sup>66</sup> and involves placing pieces of glass in a mould at room temperature, then heating them in the mould so that they melt into it and fill it. This is a challenging and complicated process. Mould making skills are important and kiln firing skills are essential. Kiln casting/slumping glass this technique also includes an alternative casting method favoured by the Romans.

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<sup>64</sup> Kiln casting is a general-purpose term that refers to the melting of glass inside a mould. It contains many of the elements of fusing and slumping but is generally more complicated and required a great understanding of warm glass principles (Walker, Brad. 1999).

<sup>65</sup> Pate de Verre is sometimes used as a generic term for kiln casting, but is actually refers to a very specialized kind of casting (Walker, Brad. 1999).

<sup>66</sup> This method was preferred by the Roman Industry during the Augustan Age. It involved the sagging of a glass blank over or in a 'former' mould while in the kiln (Klein & Ward. 1992:22).

**Definition**

Brad Walker (1999) defines kiln casting as a general-purpose term that refers to the melting of glass inside a mould inside a kiln not a furnace. He informs his readers that this technique contains many of the elements of fusing and slumping.

**Fusing** is the melting of two or more compatible pieces of glass together in a kiln.

**Slumping** can be defined as a process of heating glass until it bends to conform to a shape defined by the containing mould or by supporting wires or rods.

**Kiln cast glass** involves the placing of glass particles on top of a mould to form a bas-relief or plaque; this is a simple and effective method. The various steps involved in kilns casting depend upon the particular type of casting required. They include model creation and material selection such as clay, wax or resin for making the model. Kiln casting can be done with pieces of glass of just about any size, ranging from very small pieces to large chunks that barely fit in the kiln (Walker, Brad. 1999-2006).

**Hypothesis applicable to sub-category 5.4.1: Kiln casting/slumping glass**

It is postulated that there is a relationship between the exposure times of the photosensitive glass in the cast/slumped pieces of a specific thickness under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln.

**The focus**

The focus of sub-category kiln casting/slumping was mainly on the possibility of incorporating photosensitive glass into a kiln cast piece then slumping the cast photosensitive glass piece over a mould in a second firing.

## **Objectives**

My objectives for sub-category 5.4.1: Kiln casting/kiln slumping glass was to find as many ways possible to incorporate photosensitive glass into this warm glass technique.

## **History**

Many casting methods existed during the times between the Bronze Age and late Roman age. Casting with moulds was a technique started during the Bronze Age and continued until late Roman times. Egyptian faience was a glass-like substance made from powdered quartz and when placed into a mould and heated, a glass-like object was formed. A simple method of casting was discovered by Mycenaean warriors who forced hot glass into open moulds to create beads. During the Roman period two or more inter-locking moulds that were used to create blank glass dishes. Glass could be added to the mould either by chips casting, where the mould was filled with chips of glass and then heated in a kiln to melt the glass, or by pouring molten glass into the mould directly from the furnace. The method of ‘sagging’ or ‘slumping’ a glass blank over or in a former mould when in the kiln was preferred by the Roman Industry during the Augustan age (Klein and Ward 1992, 11-24).

**Process** (Standard applications) and technical skills required for sub-category 5.4.1. Kiln casting/slumping glass can be seen in Appendix Biv(a) (Chapter Five) scoping Case Study Four.

**Contemporary glass artists using the traditional techniques of kiln casting/slumping are:** Leah C. Wingfield (USA), Latchezar Boyadjiev (Czech Republic), Stephen Jon Clements (USA), Michael Pavlik (Czech Republic), Arthur Sale (Tasmania), Belinda Kay (WA), Colin Reid (UK), David Reekie (UK), Tim O’Neill (USA).

### **Identification of a range of experimental issues**

My experimental issues were having access to a mould making area. Having access to a furnace at a hot glass facility so that I could acquire large chunks of used soda lime furnace glass from the re-cycling bin was a concern. Access to a kiln appropriate for kiln casting/slumping with a digital kiln temperature controller for the firing of the glass in the mould was important.

#### **5.4.1a. Scoping experiments to incorporate photosensitive glass into glass casting techniques**

Many scoping experiments were attempted. Photosensitive glass chips of various sizes, crushed and powdered photosensitive glass were sprinkled on top of the surface of crushed soda lime glass which had been placed in a mould.

##### **Results**

Unfortunately, at this stage the fired glass moulds turned out to consist of a variety of red colours, indicating that the photosensitive glass had been '*cooked*' and would not be able to benefit from ultraviolet light exposure for any length of time before being returned to the kiln for heat development. This scoping experiment I regarded as unsuccessful due to the fact that the clumps were too large.

#### **5.4.1b. Scoping experiment using pre-flamed photosensitive glass**

Further scoping experiments using pre-flamed photosensitive glass that had been made into chips of various sizes, as well as crushed and powdered photosensitive glass were treated in the same manner as the original scoping experiments using '*unflamed*' or '*raw*' photosensitive glass.

##### **Results**

The results were disappointing in that the colours produced after firing at a lower temperature of 550 degrees Celsius in the same kiln ranged from bright red to dark liverish-red (haematone).

##### **Conclusion**

These scoping experiments were both unsuccessful. In my opinion this was due to the fact that photosensitive glass needs to be '*flamed*' before exposure for a

certain length of time under ultraviolet light before being heat developed in a kiln for a certain length of time at a set temperature lower than 550 degrees Celsius.

The second set of scoping experiments using pre-flamed photosensitive glass in a mould for casting in a kiln did not produce the results that I had anticipated. I had estimated that the results achieved were because pre-flamed photosensitive glass needs to be exposed to ultraviolet light before being placed in a casting mould. As well as this observation, I believe now, that the casting temperatures required to melt the glass being cast were too high and too long for the pre-flamed photosensitive glass to produce the anticipated results.

### **Scoping case study's project aims**

This case study's aims for sub-category 1 kiln casting/slumping were to find ways through experimentation how to incorporate photosensitive glass into the traditional kiln casting/slumping techniques.

### **Issues**

Physical Issues and theoretical issues were the similar to the issues in the previous case studies.

### **Sub-category 5.4.2: Simple Open Face casting/forming (Pate de Verre).**

#### **Introduction**

Pate de Verre is a warm glass technique and is another specialized form of kiln casting and literally translated means paste of glass. My adaptation of the ceramic triaxial blending technology to a triaxial glass blending technology followed consultation and discussions with Adjunct Professor John Teschendorff and is discussed in this sub-category concerned with open-face casting/forming. Triaxial blends are used when a researcher wishes to explore the results of more than two mixtures. Using the triaxial ternary system, variations in colour involving three glasses were a basis for greater visual control, leading to continued experimentation. A Line-blend involves two materials and is more suitable for simple glass making procedures such as stringer pulling, rod making and murrine

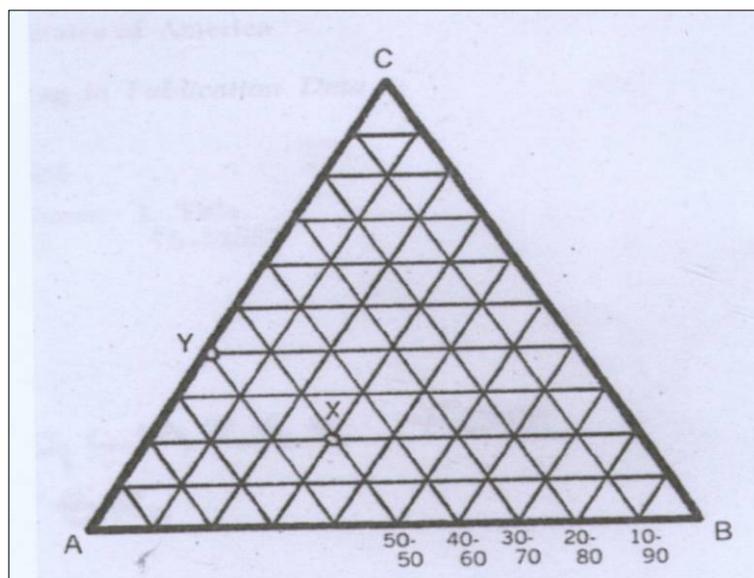
making. Robert Fournier (1992, 292) argues that the potential of using this diagrammatic ternary system is one method of studying the effects of various mixtures possible with three materials or colours as well as illustrating two line blends in the same test.

**Research question** (and specific hypothesis) **that was applied to sub-category 5.4.2.** What methods can I apply to incorporate photosensitive glass into the traditional technique of Pate de Verre?

### Solution

My adaptation of the ceramic triaxial blending technology to a triaxial glass blending technology was an experimental solution to the research question and involved the crushing of '*flamed*' photosensitive glass separately then combing percentages of the three glasses being used in the experiment as set out in the selected triaxial blending diagram. The sizes of the crushed glass particles optimum for the scoping experiments were experimental and based on the sugar granule sizes comparisons of natural brown sugar illustrated in Figure 26, Scoping Case Study Two, Chapter Two.

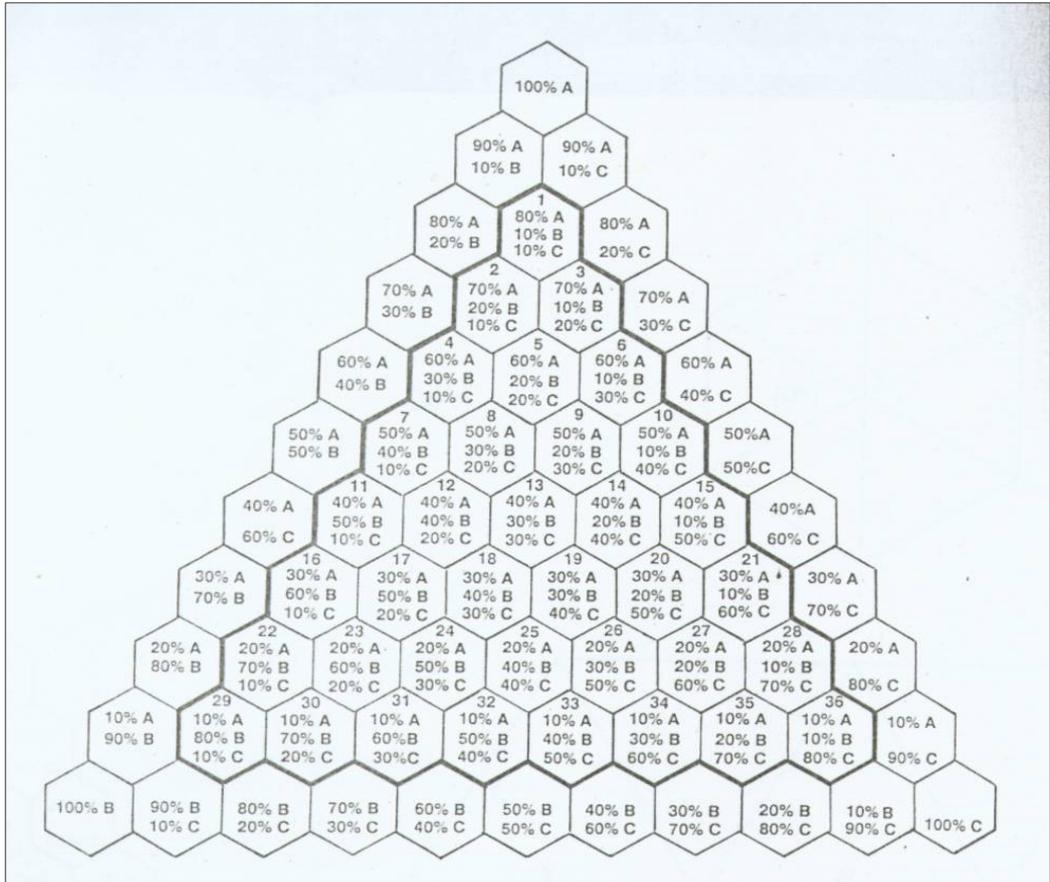
**Figure 42:** Triaxial blending diagram



Rhodes (1973, 261) describes Figure 42: Triaxial blending diagram as follows:

*“In this diagram, the points on the line between A and B and C are, in effect, the same as straight line blends. The mid-way point in each line represents half of one member and half of the other. Other points on the outside lines of the triangle have more or less of the end members, depending on the position of the point, each point in this case representing one tenth of the line. The composition of point Y, for example, will be 60 percent of A and 40 percent of C. The composition of a point on the inside of the triaxial blend will depend on its distance away from the points at the corner. Point X, for example, will contain 50 percent of A, since it is five spaces removed from A. X will contain 30 percent of B, since it is seven spaces removed from B, and 20 percent of C, since it is eight spaces removed from C”.*

**Figure: 43:** A triaxial blend of three materials



The above diagram was drawn by Peter Bramhal (1996) and illustrates the triaxial method of blending three materials. The disks inside the dark line show blends of all three materials. Those for blends of two materials (as in line blends) are around the outside of the diagram, with a single material at each apex of the triangle Yvonne Hutchison Cuff (1996, 390).

**Hypothesis applicable to sub-category 5.4.2**

It is postulated that there is a relationship between the exposure times of the photosensitive glass chips of a specific size in the triaxial blend under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln.

## **Objectives**

By using the triaxial blending ternary system, variations in colour, involving three glasses were my basis for greater visual control and colour development that led to continued experimentation. A line-blend involves two materials and is more suitable for simple glass making procedures.

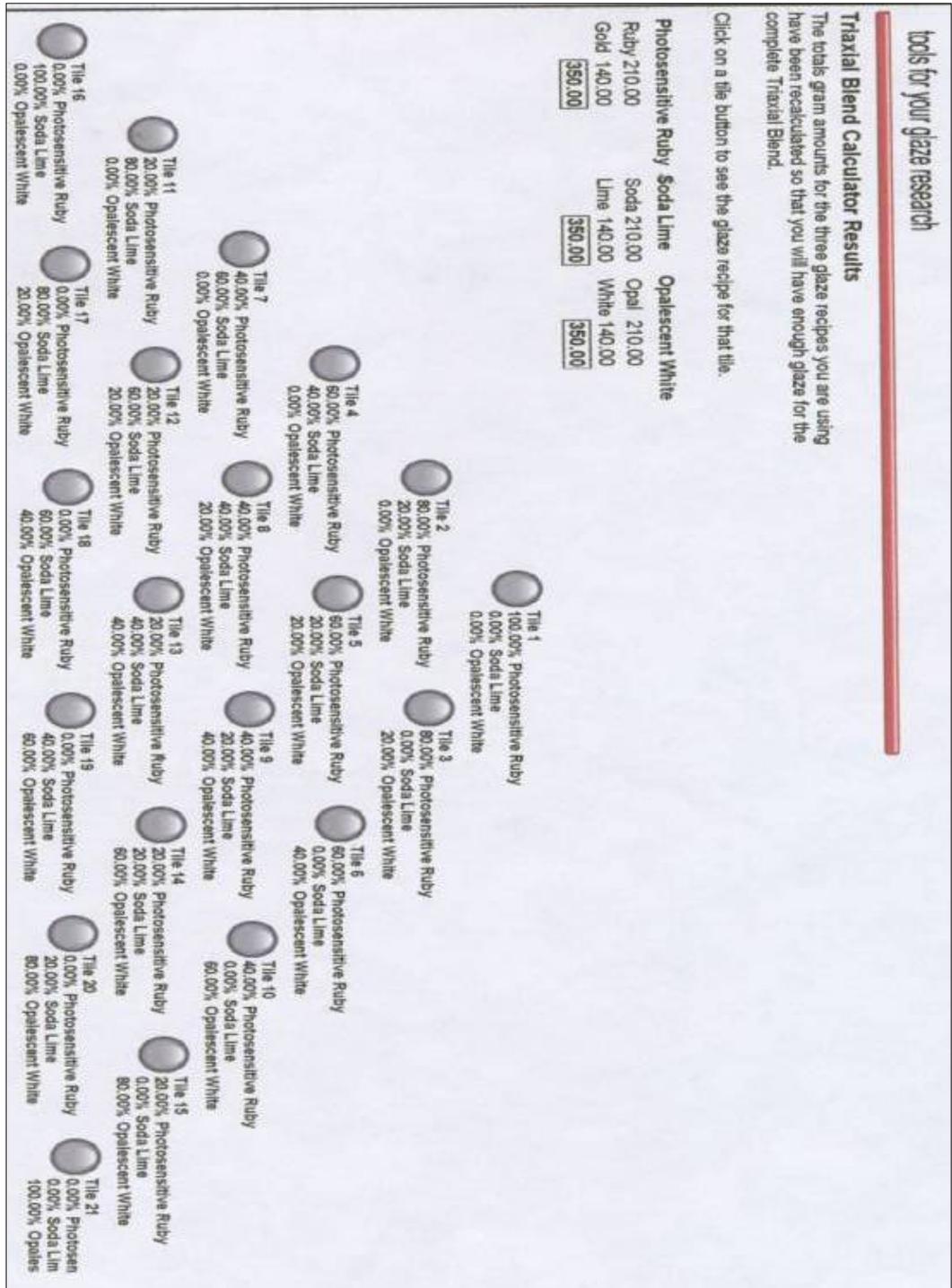
## **Contemporary artists using the triaxial blending system**

Stove (1991, 54 - 55) used the triaxial method of blending colours in her wool dyeing experiments using Merino and Superfine wools. Metals suitable for enamelling: Gold. The Society of Dutch Enamellers (1986) used a triaxial diagram of gold-silver-copper alloys in their article. Daniel Rhodes (1973, 216) used the triaxial blending method for compounding and blending of coloured glazes.

## **Designing the scoping experiments for triaxial blending**

Calculations for the scoping experiments using Gaffer #80 Photosensitive ruby glass, clear-used Soda-lime glass from the furnace and Gaffer #101 Opalescent White glass were made using a Triaxial Blend Calculator @ <http://www.triaxialblend.com> and the total gram amounts for the three glasses being used were calculated from <http://www.triaxialblend.com/CalculatorResults.aspx>. A twenty-one glass blend triangle rather than a six or ten blend triangle was selected so that the fraction of subtle change between each disk mixture would be a twenty percent or one fifth difference.

Figure 44: Diagram of a 21 triaxial blend.



Courtesy by GoDaddy.com (2008).

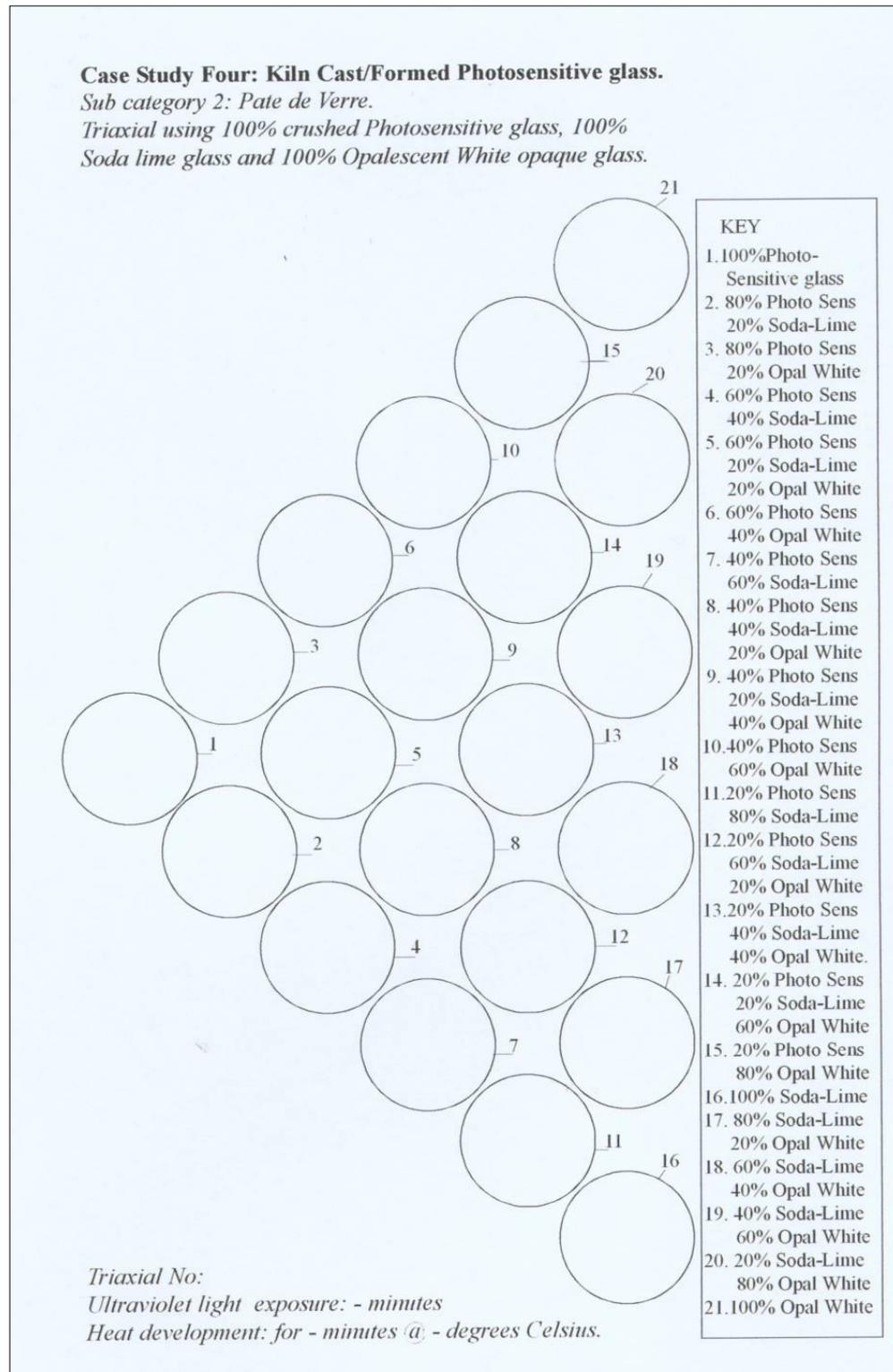
### **Experimental issues**

The experimental issues that concerned me were the estimation of the optimum sizes of the crushed glass chips, the weighing up of the correct amounts of the glass materials using a triple balance scale and working under safe red photographic light to exclude any latent ultraviolet light while the experiments were being conducted.

### **Focus**

My focus on using a triaxial blending system was on the possibility of variations in colour development that involved three different varieties of glass for greater visual control rather than relying on the two glasses that I had been using to incorporate photosensitive glass into the selected traditional techniques of glass making. Robert Fournier (1992, 292) states that the potential of using this diagrammatic ternary system is one method of studying the effects of various mixtures possible with three materials or colours as well as illustrating two line blends in the same test. Processes that were applied to sub-category 5.4 2 can be seen in Appendix Biv(b) (Chapter Five) scoping Case Study Four.

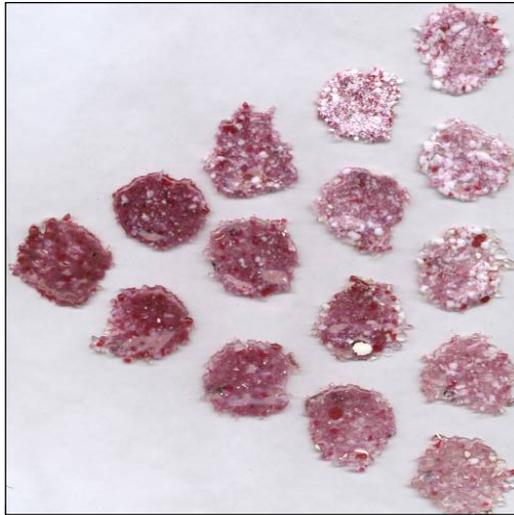
**Figure 45 (a):** Triaxial Diagram and Key



**Figure 45(b):** 5.4.2. Original triaxial scoping experiment layout  
Ultraviolet light exposure 10 minutes.  
Heat development @ 505 degrees Celsius for 120 minutes.



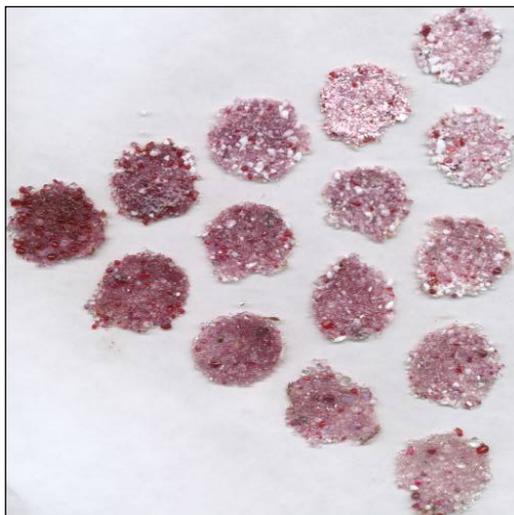
**Figure 46:5.4.2.** First Scoping Triaxial blending experiments



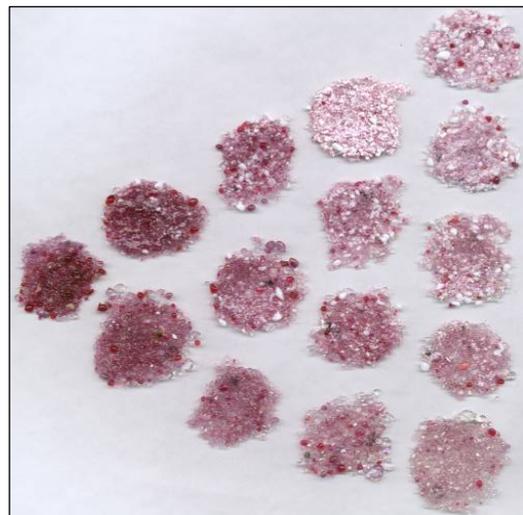
**Scoping Triaxial No: 5.**  
*UV exposure: 20 minutes*  
*Heat development: @550 degrees Celsius*  
*for 180 minutes.*  
**Colour development** shows reds, pink-reds, orange-reds, one orange, assorted pink, cherises, six blues, one violet and four mauves.



**Scoping Triaxial No: 19**  
*UV exposure: 20 minutes*  
*Heat development: @525 degrees Celsius*  
*for 180 minutes.*  
**Colour development** shows mainly reds, pinks, pink/reds, pink/oranges, six blues, mauves, one purple, two violets and two oranges amongst the pin/reds and cerise.



**Scoping Triaxial No: 31**  
*UV exposure: 20 minutes.*  
*Heat development: @505 degrees Celsius*  
*for 180 minutes.*  
**Colour development** shows ten blues, seven violets, five mauves, four purples, three oranges amongst a variety of pinks.



**Scoping Triaxial No: 46**  
*UV exposure: 20 minutes.*  
*Heat development: @495 degrees Celsius*  
*for 180 minutes.*  
**Colour development** shows fifteen mauves, eleven blues, eight violets, two purples and two oranges.

## **Discussion**

The illustrated examples of the scoping triaxials shown above were all exposed to ultraviolet light for 20 minutes then heat developed in a HARCO controlled electric kiln for 180 minutes. The heat development temperatures were tested at 550, 525, 505 and 495 degrees Celsius.

## **Results**

The grains of glass in the blend have adhered together well, forming a strong body of glass material. The colour range in each scoping triaxial indicated that the number of blues, mauves, violets, purples and oranges was based upon the development temperature of each triaxial.

## **Conclusion**

This scoping experiment was very successful in showing wide colour development range. The textures resembled molten marble-like material and I believe that the potential outcome of these scoping experiments would be commercial. Kitchen bench tops and splash backs when polished are an example. I concluded that the four scoping triaxials indicated that further research for a broader range of colour development using this system had potential towards an original contribution to glass art.

## **Case study project aims**

The aims of this sub-category was to investigate whether it would be possible to broaden the range of colour development by using a twenty-one triaxial blending system using photosensitive glass and two other different glass materials

## **Issues**

### **Physical Issues**

The crushing, sieving and categorising the sizes of the chips of the crushed glass was an issue as was the careful mixing of the three glasses that made up the triaxials. The issue of making up the triaxials for the three experiments was overcome by using a triple balance scale working under safe red photographic

light. The storage of the triaxial mixtures was solved by using black photographic plastic envelopes. Once the triaxial mixtures had been exposed to ultraviolet light, the exposed packets of the mixtures were stored in a well identified separate black plastic photographic packet ready for heat development. The issue of further exposure to latent ultraviolet light while placing the triaxial mixtures into the mould mix 6 containers was solved by placing circles of black art-paper over the mould mix 6 containers as soon as they received their contents. When all 21 containers had been filled, the black circles of paper were quickly removed then the kiln lid was lowered and the heat development cycle was started.

#### Theoretical Issues

The theoretical issue of bias was similar to that in all the case studies and their sub-categories.

## **5.5.0. Scoping Case Study Five: [Furnace Casting] (Hot-glass)**

### **Introduction**

This case study discusses the traditional glass-making technique of casting molten glass directly from the crucible of the hot glass furnace. Casting glass directly from the crucible of the furnace is accomplished by using a specially made ladle or ‘scoop’ with a long handle. This ladle is used by the glass artist to remove the hot slippery glass by dipping the bowl of the ladle into the molten mass of glass in the crucible then removing it from the furnace before pouring the hot glass out into a mould. Blowing skills are not necessary but mould-making skills are important

There are four sub-categories that represent potential scoping case studies.

Sub-category 5.5.1: Sand Casting, figure 18(e) page 109

Sub-category 5.5.2: Forcing hot molten glass into metal moulds, figure 18(e) page 109.

Sub-category 5.5.3: Casting into a variety of moulds, figure 18(e) page 109.

Sub-category 5.5.4: Casting of molten glass into a mould and then sprinkling crushed or powdered photosensitive glass into and onto the hot cast glass. Figure 18(e) page 109.

### **Stated purpose and objectives of this scoping case study**

The purpose and objectives of this scoping case study were to find ways, through systematic experimentation how to incorporate photosensitive glass into the four sub-categories of this traditional direct casting technique so as to be able to cast clear glass objects with photosensitive glass incorporated so that design elements could be placed within the glass body using ultraviolet light exposure and heat development.

## **Definition**

The temperature of the casting glass from the furnace is about 1200 degrees Celsius (2,220 degrees Fahrenheit). The molten glass has a '*slippery*' (hard to hold onto) consistency. It glows orange in colour as it comes out of the furnace in the ladle. Casting directly from the hot glass furnace using a special 'scoop' or ladle is a simple and direct activity. The glass can be cut with special shears as it is poured from the ladle into the mould.

## **An overview of each scoping sub-category**

**Sub-category 5.5.1:** Sand Casting is a simple and direct method of pouring molten glass into a special sand to produce sculptural forms.

**Sub-category 5.5.2:** Involves the forcing of hot molten glass into an open metal mould to create beads.

**Sub-category 5.5.3:** Involves the casting of coloured rods of glass together with molten photosensitive glass into sculptural moulds and annealing the glass in the mould in a kiln.

**Sub-category 5.5.4:** Involves the casting of molten glass into a mould and then sprinkling crushed or powdered photosensitive glass into and onto the hot molten glass during the process.

## **Solution/s to the research problem**

By applying the experimental form of the scientific method, the techniques of direct casting for the four sub-categories were subjected to several random scoping methods in order to answer my questions.

## **Objectives**

My objectives were to be able to cast clear glass objects with photosensitive glass incorporated so that design elements could be placed within the glass body using ultraviolet light exposure and heat development.

## **History**

Ancient glass making techniques consisted of four major manufacturing methods (with many variations, both major and minor) and were standardised. The four techniques were Rod and core forming, casting with open and closed moulds, Free blowing, blowing into moulds and forms of various kinds.

*“These techniques have been deduced from physical examination and scientific analysis of ancient pieces, analogy to contemporary practices, and modern attempts to reproduce glassware in the ancient manner. Despite such studies, however, a good deal remains to be learned about the actual workings of ancient glass factories and about specific glass-making methods. Tableware was reproduced in numerous centers and cultures over many centuries, and so it is unlikely that there were uniform procedures or a common development. Indeed, most recent research has revealed an unexpectedly rich variety of techniques, tools, and practices in diverse times and places.”*(Klein and Ward 1992, 10).

### **Sub-category 5.5.1: Sand Casting**

Sand casting is a simple and direct method of pouring molten glass into a special sand to produce sculptural forms.

## **History**

Sand casting was thought to have come about because of a need to produce blown bowls which would fit onto the outside of another bowl usually made of silver. The inner bowl would be pressed into damp sand, removed carefully and glass would then be blown into the resulting depression to form the outer bowl. It is now a common technique for producing quick sculptural pieces (Bray 2001, 209).

### **Contemporary Glass artists using this traditional technique**

Contemporary Glass artists using this traditional technique are Lucartha Kohler (USA), Bertil Vallien (Sweden), Trudy Hardman (WA), Pam Stadius (NSW), Tim O’Neill (USA).

**Processes** (standard application) and technical skills **Sub-category 5.5.1: Sand Casting** can be seen in Appendix Bv (Chapter Five) scoping Case Study Five.

#### **Overview of Sub-category 5.5.2: Casting directly into open and closed moulds**

This method involved the forcing of hot molten glass into an open metal mould to create beads.

#### **History**

Forcing or casting hot molten glass into open metal moulds to create beads was another technique used in the Bronze Age. Similar casting into metal mould techniques was used in the Roman Empire. During the late Roman times many casting methods were used to produce articles ranging from table ware and containers to beads, jewelry, inlays, plaques and window-panes. These methods used knowledge gained in the ancient metal, ceramic and faience industries.

*“Egyptian faience was a glass-like substance made principally from powdered quartz). At its simplest, casting might involve the forcing of hot glass into an open mould to create beads, such as those favoured by Mycenaean warriors”* (Klein & Ward 1992, 10).

#### **Contemporary Glass artists using this traditional technique**

David Flowers (University of Sunderland), Trudy Hardman (Perth WA).

**Process for the technique of casting into metal moulds** can be seen in Appendix Bv (Chapter Five) scoping Case Study Five.

#### **Overview of Sub-category 5.5.4: Casting into metal moulds**

Casting directly from the hot glass furnace is a simple and direct activity requiring team work. Blowing skills are not necessary but mould-making skills are important.

**Figure 47:** Scoping Experiment 1. Casting into a simple square metal mould. A simple square metal mould was used.



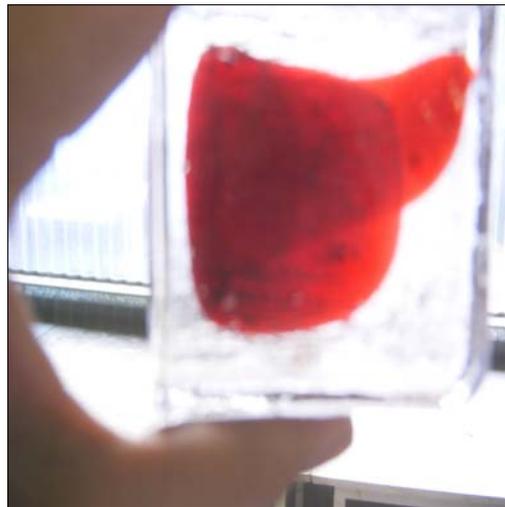
*1. Dropping molten photosensitive and furnace glass into metal mould.*



*2. Heating the cast glass with LPG gas hand-held canister.*



*3. Transferring the cast object onto wooden paddle en route to annealing kiln.*



*4. UV exposed and heat treated photosensitive cast glass within square of clear furnace glass.*

**Figure 48:** Scoping Experiment 2a. Casting double layers in a metal house mould.



*1. Photosensitive glass powder sprinkled in between two layers of cast furnace glass.*

**Figure 49:** Scoping Experiment 2b. Three layers of glass used for casting.  
Casting into house shaped a metal mould using three layers of furnace glass.  
Two layers of sprinkled photosensitive glass were placed between three layers of hot poured furnace glass into a metal mould.



*1. Photosensitive glass powder sprinkled in between three layers of cast furnace glass.*

**Figure 50:** Scoping Experiment 3. Casting into a metal cross shape  
Casting into a cross shaped metal mould using a single layer of furnace glass.



*1. Photosensitive glass powder sprinkled on top of cast furnace glass*

### **The focus**

The focus on the four sub-categories of scoping Case Study Five was based on the appeal of the instantaneous results of this exciting technique.

### **Case Study Project Aims**

The aims for this scoping Case Study: sub-category 5.5.1 were to research and experiment with the incorporation of photosensitive glass into the traditional hot glass technique of casting directly from the glass furnace. Many innovative methods as possible were used to provide new opportunities to find a quick and novel way of producing art-glass pieces.

### **Issues**

The physical and theoretical issues were similar to those described in previous case studies.

### **Outcome/results applicable to the four sub-categories**

None of the above scoping into moulds or sand casting experiments were successful. It was assumed, based on previous experiments in some of the other selected traditional techniques incorporating photosensitive glass, that crushed sieved chips or grains of photosensitive glass could be used in all four furnace casting sub-categories.

Scoping experiments were attempted but the results were unfavourable due to the intense high temperature of the soda-lime glass in the scoop coming out of the furnace when it was mixed with the powdered photosensitive glass. After annealing the scoping casting experiments in an electric kiln, the dull red liverish colours of the moulded pieces indicated that the photosensitive glass had been '*cooked*' and therefore was not suitable for exposure under ultraviolet light. A second attempt using '*flamed*' photosensitive glass in a similar manner was equally unsuccessful with similar dull red liverish (haematone) colours being produced. This case study was therefore abandoned.

## **5.6.0. Scoping Case Study Six:** [free blown glass & blowing a glass bubble into a mould] (Hot glass)

### **Introduction**

Several trial blowing experiments were made to establish starting point for this Case Study. After the unforeseen cessation of the Bullion or Crown scoping experiments in sub-category 5.0.3. of Case Study One, a few colleagues at the Hyaline Hot Glass Studio in Mount Lawley, Perth, Western Australia, collaborated by assisting me with the continuation of this particular research interest into bullion or crown making by blowing small photosensitive glass disks for the scoping experiments involving the incorporation of photosensitive glass into free blowing and mould blowing.

There are three sub-categories that are suitable for this potential scoping case study.

**Sub-category 5.6.1:** Free blowing<sup>67</sup>, figure 18(f) page 110.

**Sub-category 5.6.2:** Mould blowing<sup>68</sup> (blowing photosensitive glass into a mould using a blowing iron). Figure 18(f) page 110.

**Sub-category 5.6.3:** Adding crushed photosensitive glass to the blown molten furnace glass, figure 18(f) page 110.

**Sub-category 5.6.4:** Free blowing a photosensitive Crown or Bullion, cutting it up and exposing the cut pieces to ultraviolet light before picking the exposed piece up onto a gather of hot glass on a blowing pipe. Figure 18(f) page 110.

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<sup>67</sup> The process of introducing air into glass for the purpose of forming hollow ware (Bray 2001, 80).

<sup>68</sup> Blowing into moulds is general practice. Most of the moulds used are cast steel, graphite or wooden (Bray 2001, 53).

### **Overview of each sub-category**

**Sub-category 5.6.1:** Free blowing of photosensitive glass combined with traditional soda lime furnace glass using a blowing pipe. An assistant or a team of assistants is preferable.

**Sub-category 5.6.2:** Free blowing a photosensitive glass piece then placing it in a mould to reshape the form and/or to give the surface texture from the surface of the mould. Blowing a glass bubble into a mould.

**Sub-category 5.6.3:** Adding crushed photosensitive glass to the blown molten furnace glass.

**Sub-category 5.6.4:** Free blowing a photosensitive Crown or Bullion, annealing it, then cutting it up into pieces. The pieces can then be exposed under ultraviolet light before pick-up with a hot gather of glass on a blowing pipe.

### **Research question (and specific hypothesis) that was applied to all the sub-categories of scoping case study six**

What methods can I apply to incorporate photosensitive glass into the traditional technique of free blowing glass?

### **Solution/s to the research problem**

By applying the experimental form of the scientific method, the varied techniques of free blowing and mould blowing were subjected to several random scoping experiments that were applied to each sub-category.

### **Hypothesis applicable to all three sub-categories**

It was postulated that there is a relationship between the exposure times of the blown photosensitive glass bullion or crowns of a specific thickness under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln.

## **Objectives**

My objectives in continuing with the Bullion or Crown sub-category of scoping Case Study One, was that I believed that by incorporating photosensitive glass into this particular glass technology of the late 19<sup>th</sup> century together with innovative adaptation of some of the old alternative photographic printing processes the outcome could be used in a creative and innovative glass design practice.

## **History**

The Roman glass industry, under the Julio-Claudian emperors exploited the techniques of free-blowing that are still in operation today. The techniques of free blowing glass evolved in the second half of the first century BC in the Syro-Palestinian region. These techniques enabled glass-makers to produce vast quantities of desirable and inexpensive glass ware for daily use of all classes of Roman imperial society leading to the discontinuance of most core making and casting procedures (Klein and Ward 1992, 28).

### **Blowing into moulds and forms of various kinds.**

Moulds, manufactured from wood, ceramic, or even metal, were especially popular in the first and second centuries AD, for drinking cups and beakers with scenes of the amphitheatre and circus, often with Greek and Latin inscriptions, or for containers in the form of human heads. Experiments with mould blowing led to the development of Roman prismatic or square bottles, the forerunners of all subsequent glass containers made by a comparable process. The invention of glass blowing led to the blowing pipe (paraison) being inflated entirely or partially inside a hinged mould. An impressed decorative pattern and the shape of the mould left the glass blower with a finished vessel. A variation on the mould-blowing process involved further inflating the vessel once it had been lifted from the mould, causing the shape and decoration to become less pronounced, or twisted in a uniform manner by the rotation of the vessel on the pipe. Such expanded, mould-blown wares were particularly common in the late Roman and early Byzantine periods, when glass-

makers blew vessels into wire forms or matrices, then further inflated them, to produce patterns of indistinct ridges and grooves or other geometric designs (Klein & Ward 1992, 28).

### **Contemporary Glass Artists using this technique**

Contemporary glass artists using this ancient traditional technique are Dale Chihuly (USA), Neil Wilkin (UK), David Hay (WA), Holly Grace, (WA), Jasper Dowding, (WA) and Nick Mount (Victoria), Luke Jacomb (NZ).

### **Focus of each sub-category**

**Sub-category 5.6.1:** Free blowing. The focus on this sub-category was to incorporate photosensitive glass combined with traditional soda lime furnace glass using a blowing pipe to make a colour wheel for making Bullion or Crowns.

**Sub-category 5.6.2:** Blowing a glass bubble into a mould with photosensitive glass incorporated was the focus of this sub-category

**Sub-category 5.6.3:** The focus of this sub-category was adding crushed photosensitive glass to the blown molten furnace glass then blowing it into a mould or making a disk, Bullion or Crown.

**Sub-category 5.6.4:** The focus of this sub-category was to free-blow a Crown or Bullion, anneal it then cut it up into the sizes required before exposing an image onto the cut piece under ultraviolet light. Croucher ( 2011, 24, 10) claims that an average photographic negative will filter the radiation and so three to ten times ultraviolet light exposure may be required to produce a good image. It must also be remembered that is it important to use a compatible soda lime glass with minimal iron content. The exposed pieces are kept warm in a Lehr kiln ready for picking up onto a gather of glass on a blowing pipe ready for blowing an art-glass piece. This technique eliminates the need for ultraviolet light exposure then heat development of an image in the already blown piece in an electric kiln. *“It also became rapidly apparent, that where the glass was to be employed as a flashing, the*

*wt. percent quantity of gold incorporated was doubled to 0.04 wt. percent, and the cerium oxide increased to 0.05 wt. percent. This had a substantial effect on the density of the colour, confirming the results of Dwivedi and Nath (1977,78). While this doubles the cost of the glass it is also used in an economic manner. With thick sections of glass, say greater than 5mm, a sufficient density of colour would be achieved with the old content as low as 0.01 wt. percent” (Coucher, 1991,36).*

### **Identification of a range of experimental issues**

Blowing skills were essential and access to a hot glass furnace was essential. This is a difficult and complicated technique to master therefore it was necessary to collaborate with a skilled glass blower. My experimental issues were to get a set of photosensitive glass disks, Bullion or Crowns blown by a competent glass blower. Secondly, it was important to correctly anneal the newly blown set of photosensitive glass disks so that they would not shatter when undergoing heat development in an electric kiln after being exposed to ultraviolet light to set the colour. Thirdly, it was important to establish clear colour development areas on the photosensitive glass disk that would indicate the length of time they were exposed to under ultraviolet light. The making of moulds was a complex task so the identification of moulds that would be most suitable for blowing hot glass into was another experimental issue.

### **Scoping Experiments**

Scoping experiments to determine the amount of photosensitive glass needed to develop colour using timed ultra violet light exposure and timed heat development in a digitally controlled kiln, were the first steps taken. The small blown photosensitive glass disks were annealed overnight in the annealing kiln then exposed for intervals of ten minute intervals in an ultraviolet light box before being heat developed in a digitally controlled electric kiln for a certain length of time at temperatures ranging from 520, 525 and 575 degrees Celsius. Kiln firing

schedules were manipulated to achieve a positive outcome then a pilot experiment was made to refine the firing procedure.

**Process** (standard applications) and technical skill required sub-categories of 5.6.0.scoping Case Study Six [free blown glass & blowing a bubble into a mould] (Hot glass) can be seen in Appendix Bvi (Chapter Five) scoping Case Study Six.

**5.6.1a. Scoping experiment 1:** Trial exposures of photosensitive glass disk 7.

Disk 7: Gaffer #080 photosensitive glass over Gaffer Opalescent White glass #101 encased in soda-lime glass.

This disk was exposed under ultraviolet light at 10 minutes intervals then heat developed for 200 minutes at a temperature of 575 degrees Celsius.

**Result**

A good positive result was seen of graded mauve from 10 minutes to deep purples at 40 minutes and dark indigo violet at 120 minutes.

**5.6.1b. Scoping Experiment 2:** Trial exposures of photosensitive glass disk 8.

Disk 8: Clear Gaffer #080 photosensitive glass incased in soda-lime glass

This disk was exposed under ultraviolet light at 10 minute intervals up to 120 minutes then heat developed in an electric kiln for 180 minutes at a temperature of 525 degrees Celsius.

**Result:**

A pale mauve colour with flecks of purple red was the '*strike*' result of the temperature being too low for heat development.



### **5.6.1c. Scoping Experiment 3:** Trial exposures of photosensitive glass disk 9.

Disk 9: Clear Gaffer #080 photosensitive glass incased in soda-lime glass

This disk was exposed to ultra violet light for 10 minute intervals as done in disks 7 and 8. It was heat developed in an electric kiln for 180 minutes at 520 degrees Celsius.

#### **Result**

A very poor result was seen, practically no colour at all except for threads of pink within the glass body. This disk did not '*strike*' possibly because of the low temperature during heat development or lack of opalescent white backing.

#### **Conclusion**

My decision to continue with further experimental research was based on the scoping experiment Disk 7 using Gaffer #101 Opalescent White glass as a variable base under the photosensitive glass. Sub-category 5.6.2: Mold blowing with photosensitive glass incorporated into the blown body and sub-category 5.6.3. Adding crushed photosensitive glass to the blown molten furnace glass disks was not followed through due to limited collaborative issues. These two sub-categories will undergo further experimentation in my post doctoral research-led practice. Croucher ( 2011, 24, 10) claims that an average photographic negative will filter the radiation and so three to ten times ultraviolet light exposure may be required to produce a good image. It must also be remembered that is it important to use a compatible soda lime glass with a very low iron content as the sensitivity of the glass to ultraviolet light radiation decreases rapidly.

#### **Scoping Case Study project aims**

To assess and identify the amount of photosensitive glass is needed to produce a colour wheel for use when making disks, bullion or crowns and identify a suitable method of incorporating photosensitive glass when free blowing into a mould.

**Issues** – The physical and theoretical issues were similar to those previously described in the other case studies.

### 5.7.0. Scoping Case Study Seven: Acid etching<sup>69</sup>/Acid embossing (Cold glass) **Hazardous**. Figure 18(g) page 111.

#### **Introduction**

The process of acid etching on glass is not recommended except in strictly controlled certified laboratories, as hydrofluoric acid can be deadly if the correct equipment is not available for use. The problem is that acid burns can go undetected. “*Unlike other acids, dilute hydrofluoric acid can react with tissue and bone without much initial pain*”. The acid does not burn the skin at first, but penetrates directly to the bone beneath where it begins to attack and dissolve bone. If untreated, it will continue to erode, causing bone loss. **The use of Hydrofluoric Acid is a health hazard because of the gases it forms.** Inhalation of fumes can cause pulmonary oedema, even death. (Hydrofluoric Acid – Guidelines for safer handling and storage – WorkSafe Victoria, Australia, 2004). Because of this worksafe warning, research into this case study was only theoretical and no experiments were attempted.

#### **General overview**

The scientific industry uses this acid etching process in manufacturing New Bragg Grating Positioner Platforms for fibre optic use<sup>70</sup> in scientific applications.

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<sup>69</sup> A process of matting or removing the surface of glass by exposure to hydrofluoric acid or its derivatives (Bray 2001, 113).

<sup>70</sup> The Gale Group at NIST published a paper in their Journal of Research of the National Institute of Standards and Technology (Nov 2000) on the ‘*Technique Developed For Characterization Of Photosensitive Glass*’. The group found that Ultraviolet light could induce a permanent change in the refractive index of a glass material. UV photosensitivity was found to be very useful in fabricating integrated optic and fiber Bragg grating devices. Fiber Bragg gratings are wavelength-selective reflectors that can be written into the core of optical fiber used in communication systems and also make excellent strain sensors that can be networked to obtain distributed strain measurements of large structures, such as bridges and ships.

### **The stated purpose of the Scoping Case Study**

Because the scientific industry uses photosensitive glass with the acid etching process in manufacturing I was interested in discovering if it were possible to use photosensitive glass together with acid etching in an artistic environment.

### **Definition of the Scoping Case Study**

This case study has been defined as a health and environmentally hazardous research project even with suitable scientific equipment available to do the research.

### **Research question (and specific hypothesis) that was applied to the scoping case study**

How can photosensitive glass be used together with the acid etching process by the glass artist/designer in a work-safe environment?

### **Questions asked:**

Are there any glass artists researchers working with this dangerous medium at present?

### **Solution/s to the research problem**

Nancy D. Stephenson's (1986, 1359 – 1360) Paper on Photosensitive Glass Ceramics – “*A New Generation: Aesthetic applications of photosensitive glass-ceramic technology*”, described etching to be the third step in the process of using the material known as ‘Opelle’<sup>71</sup> as a decorative medium. It was an informative paper that dealt with the theoretical aspects of the solution to my research problem Stephenson's paper described the unique process used in the manufacture of the decorative glass-ceramic products. A breakdown of the raw components was listed. Her paper describes how the raw materials are melted then rolled into sheet

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<sup>71</sup> “*Aesthetic applications of photosensitive glass-ceramic technology, trademarked as OPELLE has been called the decorating Industry's most unique achievement in recent years. With this process, the most intricate details of a drawing are permanently developed in a glass plate once exposed to uv light. Subsequent acid etching and ceramic firing results in a decorative glass-ceramic with both textural and line qualities*” (Nancy D. Stephenson, 1986, Corning Glass Works, Corning, NY 14831).

form, ready for further manipulation. The blank sheets of photosensitive glass in sheet form are produced in 1.44 mm, 2.03mm and 2.67 mm thicknesses. Stephenson (1986) describes these blank sheets as creating the ultimate form. A four step process consisting of exposure, development, acid etching and ceramic firing enables the chosen design to be permanently captured within the body of this special material known and registered as OPELLE.

### **Objectives**

My objectives were to discover how Nancy D. Stephenson used photosensitive glass technology as a decorative medium.

### **History**

The most significant new decorating technique to be introduced during the Victorian period was acid-etching (Klein & Ward 1992, 180-181).

Glass workers made their own hydrofluoric acid in the early part of the 19<sup>th</sup> century because it was possible to buy acid in gutta percha containers from manufacturing chemists. The pernicious nature of the process of making hydrofluoric acid for etching did not make the practice desirable. It remained a risky undertaking because there were not air-extraction systems to remove the noxious fumes (Fluorine F<sub>2</sub>). Duthie (1908) describes the fumes that escaped from full strength acid to visibly resemble a yellow smoke-like substance, and are not only obnoxious, but dangerous. Even at moderate working strength the fumes will cause bleeding of the throat and nostrils in persons in whom these organs happen to be weak. The yellow-smoke-like fumes commonly caused severe lung problems, however these fume were claimed to have a beneficial effect in cases of pulmonary consumption (Tuberculosis), a disease which is practically non-existent among people who handle this acid. (Duthie, 1908).

One other etching agent was developed and exploited to the full during the 19<sup>th</sup> century. Known as 'white acid', it was made by mixing hydrofluoric acid with an alkali; usually carbonate of soda (washing soda) 'White acid' produced a 'frosting

acid' that imparted a dense white frost to the surface of glass. Subsequent etchings with dilute hydrofluoric acid produced a range of satin tones. This process is known in the trade as 'French embossing' or 'triple embossing' and was frequently employed in combination with brilliant cutting (Bender 1998)<sup>72</sup>.

Bender claims that the price of glass fell dramatically six years after the Glass Tax in England had been abolished in 1845. Since the year 1773, cast plate glass had been manufactured in England and was only available for the most costly of projects. With the abolition of the Glass Tax, the use of glass became common in the windows of shops and public buildings.

*"The size and thickness of plate glass compared to that of crown or cylinder sheet glass meant that it could be used to glaze large openings and it offered new possibilities for decoration. Larger window openings mean increased light and visibility. For a nation of shopkeepers this was no bad thing. However, increased visibility was not desirable in all establishments; certainly not the public house. It was here that two techniques, brilliant cutting and acid etching, came to flourish. Plate glass, because of its thickness and weight, provided the ideal surface for these decorative techniques. They in turn created privacy and enhanced illumination. Furthermore, these techniques offered the opportunity for introducing glittering and unrestrained decoration. With the exception of bottles and glass there could have been no better addition to the drunken rococo decoration of the Victorian public house. The domestic interior also became a show case for brilliant cutting and acid etching. Here the results were far more temperate than the public house. Designs usually reflected the prevailing classical taste. Door and window panels of brilliant cut and acid etched glass were frequently used in Victorian and Edwardian interiors to obscure unsightly views and to increase privacy without sacrificing daylight. Acid frosted glass had the virtue of eliminating transparency whilst heightening the sense of illumination due to the way it scattered light. From the 1860's acid etching and brilliant cutting were widely employed for commercial promotion. Shop fascias, advertising boards and even tradesmen's vans were fitted with decorated plate glass signs. So widespread was the use of glass that the sign writer soon found the craft of acid etching an indispensable addition to his trade" (Bender 1998).*

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<sup>72</sup> Rodney Bender is a glass artist and maker. He is a fellow of the British Society of Master Glass Painters and is Course Director of Architectural Glass at Swansea Institute of Higher Education.

### **Artists using this technique**

In 1938 designer Flavio Poli designed a series of animals that were blown personally by Archimede Seguso and finished in the corrosive technique using hydrofluoric acid, a technique not in use since the 1860s<sup>73</sup>. Included within this series was a figure of a hippo semi submerged with its mouth closed. An example of this can be found in the book “Animals in Glass” as item no 64. Acid etching is still widely used.

### **Focus of this Scoping Case Study**

The focus of this case study was on using photosensitive glass and acid etching as an artistic medium.

**Process** (standard application) and technical skills required can be seen in Appendix Biv (Chapter Five) scoping Case Study Seven.

The Acid Etching Process involves the use of an acid that will rapidly corrode glass. Nancy D. Stephenson’s (1986, 1359 – 1360) Paper on Photosensitive Glass Ceramics – A New Generation, described etching to be the third step in the process of using the material known as ‘Opelle’<sup>74</sup> as a decorative medium. My understanding of Nancy Stephenson’s four-step decorative acid etching process of the material registered as Opelle can be seen in Appendix Bvii (ChapterFive) scoping Case Study Seven.

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<sup>73</sup> “A design is masked out on the surface of the object and then placed in a bath of a dilute solution of acid. The acid attacks the silicates in the exposed areas, breaking them down to form silicon fluoride gas. The gas escapes, resulting in a corrosion of the surface; when the desired depth of corrosion is obtained, the acid is neutralized by water”. Water will not neutralize the acid, it simply dilutes it. Alkalis such as NaOH are used to neutralize the acid (Sale.2011). <http://glassgallery.yobunny.org.uk/displayimage.php?album=94&pos=2> 03/08/2006.

<sup>74</sup> “Aesthetic applications of photosensitive glass-ceramic technology, trademarked as OPELLE has been called the decorating Industry’s most unique achievement in recent years. With this process, the most intricate details of a drawing are permanently developed in a glass plate once exposed to uv light. Subsequent acid etching and ceramic firing results in a decorative glass-ceramic with both textural and line qualities (Nancy D. Stephenson, 1986 Corning Glass Works, Corning. NY 14831)

Because environmental and health reasons were of some concern, this scoping Case Study was not pursued.

### **5.8.0. Overview of Chapter Five**

Five successful sub-categories of each case study's scoping experiments were taken further using systematic experimentation. These successful experiments are discussed in greater detail in Chapter Six.

# **CHAPTER SIX - CASE STUDY EXPERIMENTS AND REPORTS**

## **6.0.0. INTRODUCTION**

This chapter further develops the outcomes of the successful scoping case study experiments identified in Chapter Five. I consider these experiments to be an original contribution to a glass artist's/designer's knowledge and to the discipline. The scoping experiments were discussed in Chapter Five as case studies in written report format. Soy (1997) argues that the goal of the written report format is to portray a complex problem in a way that conveys a vicarious experience to the reader. Lubbe (2003) argues that it is important that research findings are honestly presented and not produced in a way so as to simply support the opinions or prejudice of the researcher and suggests that each case study report has an outline. The final report for each of my successful case studies consists of:

- The suggested outline
- The format the structure
- The objectives
- The equipment used in each case study
- The technical processes employed such as the exposure of the experiments to ultraviolet light
- The experimental processes
- The design and construction of firing schedules
- Heat and colour development
- The measurement of my independent and dependent variables
- The experiments are presented in a written format together with graphical and visual illustrations

Case Study One:  
Sub-category 5.1.1.  
Pulling Stringers.



*UV exposure: 10, 20, 30, 40 and 50 minutes  
Heat development @ 525 degrees Celsius for 120 minutes*

The selected sub-categories 5.1.1: Stringers and canes and 5.1.2: Murrine and mosaics in 5.1.0. Case Study One: Pulling and drawing out molten glass (hot glass) is reported in full as an example of the Case Study research method applied to all the successful experiments. The same research method was used for all other experiments detailed in Chapter Six. Any exceptions of the methods outlined in 5.1.0. for sub-categories 5.1.1 and 5.1.1 are noted and the outcomes are reported in full for each experiment.

## ***Report Outline***

### **Introduction**

**5.1.0. Case Study One:** Pulling & drawing out molten glass (Hot glass).

**Sub-category 5.1.1:** Stringers or cane making.

Based on the outcome of group of stringers and canes in the scoping experiment A, Figure 19 of sub-category 5.1.1, as described in Chapter Five, this case study started with the testing of the hypothesis by action.

### ***Structure***

#### **6.1.0a. Systematic Experimentation**

Experiments in this case study sub-category consisted of pulling stringers from a hot glass furnace using photosensitive glass.

#### **Objectives**

The objective of these experiments was to test how photosensitive glass could be incorporated into this traditional glass making technique to produce a range of colours. Colour development within the stringers by timed exposure under ultraviolet light followed by timed heat development temperatures were the methods of proving that it was possible to achieve the objective.

**Process** details of the stringer experiments can be seen in Appendix Ci (a) (Chapter Six) Case Study One, sub-catetogy 5.1.1: Stringers.

### **Equipment**

A testing run of the equipment that was set up in the darkroom was made before the first experiment. Photographs were taken of the light box and all the details were written in the working note book for future reference.

### **Method: Exposing the groups of stringers under UV light**

A method of exposure under ultraviolet light for the photosensitive glass stringers was selected.

### **Planning the construction/design of firing schedules**

A series of kiln firing programs were designed for the heat development phase for each group of stringers. A pilot experiment to refine procedure was conducted.

### **Heat and Colour development**

Colour development was achieved by timed exposure under ultra-violet light, followed by heating the ultraviolet light exposed photosensitive glass stringers in an electric kiln at a defined temperature for a certain length of time.

### **Independent and Dependent variables**

The dependent variable was the intensity of the colours of the developed photosensitive glass in the stringer experiments. The independent variables were the exposure times of the photosensitive glass stringer experiments to ultraviolet light, the heat development temperatures that the experiments were fired at in the electric kiln, the length or rate of the time that the stringer experiments were held (soaked) at a designated temperature in the digitally controlled electric kiln, the type and amount of opaque glass that was added to the photosensitive glass stringer experiments and finally the thickness of the photosensitive glass in the experiment. To predict an outcome in any experimental research, some variables

are controlled and some are manipulated. Therefore it is necessary to define the basic variables then only change one variable at a time in an experiment. The dependent variable is the phenomenon that appears, disappears or changes as the independent variable is applied (Allison, O'Sullivan and Owen 1996, 7-29).

### **Stringer Experiments**

The ten stringer experiments were divided into two groups and are described as follows:

#### **Control Group @ 495 for 90 minutes.**

*Ultra violet light exposure: Nil.*

*Heat development temperature @ 495 degrees Celsius for 90 minutes.*

#### **Results:**

**Colour:** A tinge of pale pink within one of two of the stringers.

**Shape:** No alteration of shape seen. Stringers have adhered to one another

#### **Group 1.1**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development @ 495 degrees Celsius for 90 minutes.*

#### **Results:**

**Colour** Reading from left to right, the banded base of the group has a clear blue colour at ten minutes. The blue deepens in the twenty minutes band. The thirty minute band shows the blue becoming mixed with a mauve/puce colour, then the forty minutes band becomes more mauve/puce than blue. The fifty minutes band shows a puce colour.

**Shape:** The stringers have not been altered by the low heat development. The stringers have adhered to one another (tack fused).

#### **Group 1:2**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development @ 505 degrees Celsius for 90 minutes.*

**Results:**

**Colour** Reading from left to right, the banded base of the group has a clear blue colour at ten minutes. The blue deepens and becomes mixed with mauve/puce in the twenty minutes band. The thirty minutes band shows less blue, more mauve/puce in colour. The forty minutes band becomes more mauve/puce with a slight redness showing. The fifty minutes band is red in colour showing a slight tinge of mauve when held up to the light.

**Shape:** The shapes of the stringers have not been altered by the low heat development. The stringers have adhered to one another (tack fused).

**Group 1:3**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development t@ 525 degrees Celsius for 90 minutes.*

**Results:**

**Colour** Reading from left to right, the banded base of this group shows a blue/mauve colour at ten minutes. The colour becomes a mauve/puce in the twenty minutes band. The thirty minute band shows a red colour. The forty minutes band is red as is the fifty minutes band.

**Shape:** The stringers have separated due to the heat and have adhered to one another in certain areas. Some stringers appear bent.

**Group 1:4**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development temperature @ 550 degrees Celsius for 90 minutes.*

**Results:**

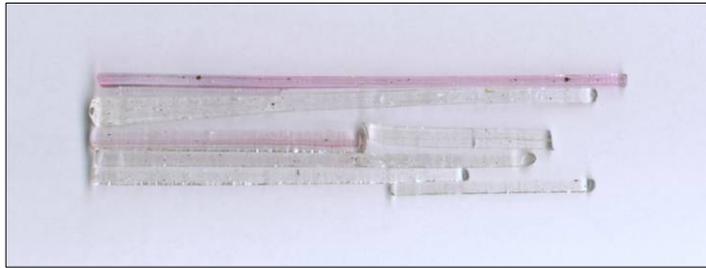
**Colour** Reading from left to right – the banded base of this group shows a red/mauve colour at ten minutes. The colour changes to red in the twenty minutes band. The thirty minute band shows a red colour. The forty minutes band is red as is the fifty minutes band.

**Shape:** The stringers did not bend but have adhered to one another (tack fused).

**Figure 52**

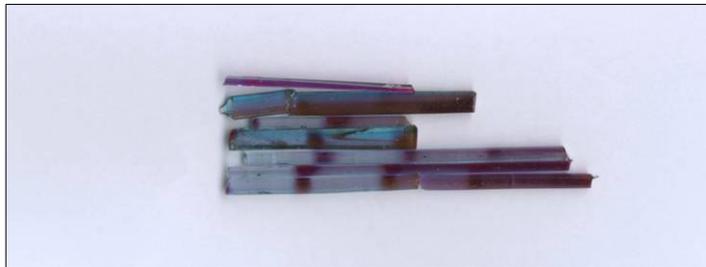
Case Study One: sub-category 5.1.1. Stringers.

**Experiment: Group 1.** *Photosensitive glass stringers exposed to UV light then heat developed in an electric kiln for 90 minutes controlled by a digital controller.*



**Control Group: 1.**

Ultraviolet light exposure: Nil.  
Heat development: @ 495 degrees Celsius for 90 minutes.



**Group: 1.1.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 495 degrees Celsius for 90 minutes.



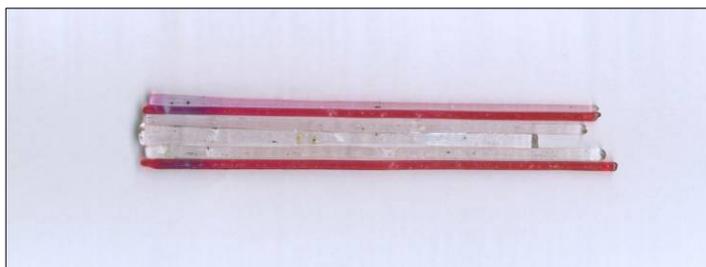
**Group: 1.2.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 505 degrees Celsius for 90 minutes.



**Group: 1.3.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 525 degrees Celsius for 90 minutes.



**Group: 1.4.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 550 degrees Celsius for 90 minutes.

**Control Group 2:****Control Group @ 525 for 120 minutes.**

*Ultra violet light exposure: Nil.*

*Heat development temperature @ 525 degrees Celsius for 120 minutes.*

**Results:**

**Colour:** A colour range from pink to clear red can be seen.

**Shape:** No alteration of shape seen and the stringers have adhered to one another.

**Group 2:1**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development temperature @ 495 degrees Celsius for 120 minutes.*

**Results:**

**Colour** Reading from left to right, the banded base of the group has a clear blue colour at ten minutes. The blue deepens and becomes mixed with mauve/puce in the twenty minutes band. The thirty minute band shows a mauve/puce colour. The forty minutes band becomes red with a slight puce tinge. The fifty minutes band is dark red in colour.

**Shape:** The stringers have not been altered by the low heat development and have adhered to one another.

**Group 2:2**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development temperature @ 505 degrees Celsius for 120 minutes.*

**Results:**

**Colour** Reading from left to right, the banded base of the group has a clear blue colour at ten minutes. The blue deepens and becomes tinged with mauve/puce in the twenty minutes band. The thirty minute band shows a mauve/puce colour. The forty minutes band becomes dark-red with a slight puce tinge. The fifty minutes band is dark red in colour.

**Shape:** The stringers have not been altered by the heat development and have adhered to one another.

### **Group 2:3**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development temperature @ 525 degrees Celsius for 120 minutes.*

#### **Results:**

**Colour** Reading from left to right, the banded base of the group has a clear blue colour at ten minutes. The blue deepens and becomes tinged with mauve/puce in the twenty minutes band. The thirty minute band shows a mauve/puce colour. The forty minutes band becomes dark puce/red. The fifty minutes band is dark red in colour.

**Shape:** The stringers have melted together due to the length and high temperature of the heat development stage.

### **Group 2:4**

*Ultra violet light exposure from ten to fifty minutes.*

*Heat development temperature @ 550 degrees Celsius for 120 minutes.*

#### **Results:**

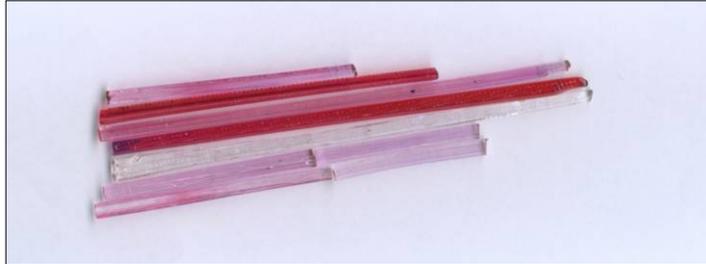
**Colour** Reading from left to right, the banded base of the group shows a red puce at ten minutes then becomes red with mauve/puce tinge in the twenty minutes band. The thirty minute band shows red in colour. The forty minutes band becomes brighter red. The fifty minutes band continues to remain the brighter red colour.

**Shape:** The stringers have melted together and become distorted due to the high temperature and length of the heat development stage.

**Figure 53:**

Case Study One: sub-category 5.1.1. Stringers.

**Experiment: Group 2.** *Photosensitive glass stringers exposed to UV light then heat developed in an electric kiln for 120 minutes controlled by a digital controller.*



**Control Group: 2.**

Ultraviolet light exposure: Nil.  
Heat development: @ 495 degrees Celsius for 120 minutes.



**Group: 2.1.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 495 degrees Celsius for 120 minutes.



**Group: 2.2.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 505 degrees Celsius for 120 minutes.



**Group: 2.3.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 525 degrees Celsius for 120 minutes.



**Group: 2.4.**

Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 550 degrees Celsius for 120 minutes.

## **Overview and outcome**

The systematic experimentation for the incorporation of photosensitive glass into the traditional technique of pulling glass stringers consisted of eight graded tonal coloured stringer experiments. The ten experiments were divided into two groups with a control experiment in each group. Two heat development time based experiments were undertaken. The results of the two systematic experiments show a successful outcome and can now be used as a reference base for future photosensitive stringers or canes used in glass art-works. However, colour comparisons of exposure times under ultraviolet light and specific heat development times in an electric kiln should always be made, because different electric kilns will produce slightly different colour results. This is important to note when applying this knowledge to any future designs involving photosensitive glass stringers.

## **Methods and procedures for collecting the data**

### **Data sources**

Data sources were determined by the results from the scoping experiments 5.1.1a and 5.1.1b and from the two systematic experimental groups that were both visually and digitally scanned before being photographed.

### **Data collection**

To prepare the data collection for this case study category 5.1.1, I photographed and digitally scanned the results of the four groups of scoping experiments 5.0.1a as well as the two groups of ten photosensitive glass stringer systematic experiments that followed the successful scoping experiments. These scanned results and photographs were my primary source materials.

### **Data presentation issues**

My data presentation issue of how to present the data from the two groups of photosensitive glass stringer experiments was solved by my solution to physically display the original experiments as well as to print out the scanned experiments results in this thesis. I then stored the scanned images on a compact disk for future

reference. Miles and Huberman (1984) suggested alternative analytical techniques of analysis such as using arrays to display the data, creating displays, tabulating the frequency of events, ordering the information and other methods. This must be done in a way that will not bias the results (Tellis 1997).

### **Presentation analysis**

The experimental results were analysed visually according to colour development and the two groups were compared based on the time taken and at the temperatures that they were heat developed.

### **Analysis of the data**

The data was analysed to estimate the development of sub-category 5.1.1. before continuing with the final experiments that were based on the successful results of the scoping experiments. All these experiments were presented and saved on a compact-disk and in photographic format in the hard copy of this thesis.

### **Interpretation analysis of my collected data**

The interpretation of the analysis of my collected data was by comparing exposure times, heat development times and the length of time the experiments were developed in an electric kiln using a digital controller.

The comparisons were visually based on colour development as well as heat distortion of the glass stringers, canes and rods.

### **Criteria for the interpretation of the results**

The criteria for the interpretation of the experimental results were that two groups of systemic experiments were undertaken. Each experimental group had a control. The ultraviolet light exposure times were similar for each group of experiments as were the heat development temperature ranges. The time that it took to develop the experiments was selected to be at two different rates.

### **Potential application**

The potential application of photosensitive glass stringers or ribbon glass could be as applied splinters to a glass-art piece. Molten blobs of photosensitive glass that

had been sufficiently heated on a punty in a glory-hole could be applied as 'prunts' or blobs (Bray 2001, 193). Photosensitive glass stringers could be wrapped loosely or tightly around a glass art work, annealed and then exposed to ultraviolet light before being heat developed in an electric kiln. Glass artist Toots Zinsky uses stringers of coloured glass to loosely build shapes such as "*Chaos Flaming again*" 1997 and "*Water spout#14*" 1994 (Kohler 1998,77). Canes and rods made from photosensitive glass could be placed into a mould and fused together in an electric kiln as the mosaic bowl by glass artist Klaus Moje's of Australia 1980 (Kohler 1998, 7). Filaments of photosensitive glass applied to clear hot glass objects while still on the blowing iron then annealed before exposing the object to ultraviolet light then heat developed. Festooned thread applications [fenicio] of photosensitive glass in combination with other coloured fenicio applications onto a blown glass piece.

#### **Application of the experimental results**

To apply the colour results shown on each stringer to future designs on work being produced using photosensitive glass it is important to compare the colours of ultraviolet light exposure times at specific heat development times for certain periods of time before deciding on the glass technique to be used such as fusing or slumping. If the glass piece is required to remain as it was, then note the development temperatures and corresponding colour exposures and the time it took to develop the desired colours. Too long a period at heat development may result in the desired colour but will cause the piece to distort. Suit the depth of colour to the length of time to preserve the shape and integrity of the glass piece.

Case Study One:  
Sub-category 5.1.2.  
Murrine.



*UV exposure: 30 minutes*  
*Heat development @490 degrees Celsius for 90 minutes*

## ***Report Outline***

### **Introduction**

#### **5.1.0. Case Study One:** Pulling & drawing out molten glass.

##### **Sub category 5.1.2:** Murrine or mosaics making.

Based on the outcome of the four groups of murrine scoping experiments, as described in Chapter Five, Case Study One, experiments incorporating photosensitive glass into canes, started with the experimental testing for colour development in photosensitive glass murrine.

### ***Structure***

#### **6.1.0b. Systematic Experimentation**

Photosensitive glass canes were pulled under safe red photographic light in the studio, using the miniature furnace as described in the pulling of photosensitive glass stringers in sub-category 5.1.1. This sub-category section deals with the making of photosensitive glass murrine by systematic experimentation.

#### **The Objectives**

The objective of these thirty-six experiments was to test whether photosensitive glass could be incorporated into this ancient traditional glass making technique.

#### **Technical process**

An outer casing of coloured glass, from the miniature furnace crucible containing the molten coloured glass, was gathered on a punty that held a disc of ‘*flamed*’ photosensitive glass. The canes were cut by hand into short oblong pieces (murrine) then sorted into twelve groups for a systematic experiment involving ultra-violet light exposures for designated lengths of time and heat development in an electric kiln for heat development at selected temperatures and times. Thirty-six experiments of murrine were set up. Heat development firing schedules used

for each group of three experiments can be viewed at the foot of the page illustrating the experimental results.

### **Equipment**

A trial run of the equipment was set up in the darkroom before the first experiment was commenced.

### **Planning the construction/design of firing schedules**

A series of kiln firing programs using Graham Stone's Firing Schedules for Glass: The Kiln Companion 2000, were designed for the heat development phase for each group of murrine. A pilot experiment to refine procedure was conducted.

### **Heat and Colour development**

Colour development was achieved by timed exposure under ultra-violet light, in a light box followed by heating the exposed photosensitive glass murrine in an electric kiln at a defined temperature for a certain length of time.

### **Independent and dependent variables**

The dependent variable was the intensity of the colours of the developed photosensitive glass in the murrine experiments. The independent variables were the exposure times of the photosensitive glass murrine experiments to ultraviolet light, the heat development temperatures that the experiments were fired at in the electric kiln and the length or rate of the time that the murrine experiments were held (soaked) at a designated temperature in the digitally controlled electric kiln, the type and amount of opaque glass that was added to the photosensitive glass murrine experiments and finally the thickness of the photosensitive glass in the experiment.

### **Murrine Experiments**

The thirty six photosensitive glass murrine experiments were divided into twelve groups and are described as follows:

**Group 1.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 490 degrees Celsius for 90 minutes.*

**Results:**

**Colour:** A tinge of mauve colour in the photosensitive glass component of the murrine can be seen surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been altered by the low heat development.

**Group 1.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 490 degrees Celsius for 90 minutes.*

**Colour:** A distinct mauve colour in the photosensitive glass component of the murrine can be seen surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been altered by the low heat development.

**Group 1.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 490 degrees Celsius for 90 minutes.*

**Colour:** A deep mauve colour in the photosensitive glass component of the murrine can be seen surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been altered by the low heat development.

**Group 2.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 495 degrees Celsius for 90 minutes.*

**Results:**

**Colour:** A faint tinge of mauve colour in the photosensitive glass component of the murrine can be seen surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been altered by the low heat development.

**Group 2.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 495 degrees Celsius for 90 minutes.*

**Colour:** A faint tinge of red in some of the mauve coloured murrine can be seen and a distinct tinge of blue present in the remainder of the photosensitive glass component of the murrine can be seen surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been affected by the low heat development.

**Group 2.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 495 degrees Celsius for 90 minutes.*

**Results:**

**Colour:** A tinge of red in the mauve coloured murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been affected by the low heat development.

**Group 3.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 505 degrees Celsius for 90 minutes.*

**Results:**

**Colour:** A faint tinge mauve colour can be seen in some of the photosensitive component of the murrine surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been affected by the medium low heat development.

**Group 3.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 505 degrees Celsius for 90 minutes.*

**Results:**

**Colour:** A pale mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been affected by the low heat development.

**Group 3.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 505 degrees Celsius for 90 minutes.*

**Results:**

**Colour:** A deeper reddish mauve colour can be seen in most of the photosensitive component of the murrine surrounded by a casing of opaque orange/yellow glass.

**Shape:** The shapes of the murrine have not been affected by the medium low heat development.

**Figure 54**

Photosensitive glass murrine: Comparative ultraviolet light exposure results.

		
<p><b>Group 1.1:</b> UV exposure: 10 minutes Heat development: 90 mins @ 490 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 90 mins @ 490 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 90 mins @ 490 degrees Celsius.</p>
		
<p><b>Group 2.1:</b> UV exposure: 10 minutes Heat development: 90 mins @ 495 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 90 mins @ 495 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 90 mins @ 495 degrees Celsius.</p>
		
<p><b>Group 3.1:</b> UV exposure: 10 minutes Heat development: 90 mins @505 degrees Celsius</p>	<p>UV exposure: 20 minutes Heat development: 90 mins @505 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heath development: 90 mins @ 505 degrees Celsius.</p>

**Group 4.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 490 degrees Celsius for 120 minutes.*

**Results:**

**Colour:** A pale mauve colour can be seen in some of the photosensitive component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have started to lose their square shapes due to the length of time they were heated.

**Group 4.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 490 degrees Celsius for 120 minutes.*

**Results:**

**Colour:** A true mauve colour can be seen in some of the photosensitive component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have started to lose their square shapes and have become rounder due to the length of time they were heated.

**Group 4.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 490 degrees Celsius for 120 minutes.*

**Results:**

**Colour:** A reddish mauve colour can be seen in some of the photosensitive component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have started to lose their square shapes and have become rounder due to the length of time they were heated.

**Group 5.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 495 degrees Celsius 120 minutes.*

Results:

**Colour:** A pale mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have started to soften and become rounder due to the length of time taken for heat development.

**Group 5.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 495 degrees Celsius 120 minutes.*

Results:

**Colour:** A pale mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have become rounder and softer due to the time taken for heat development.

**Group 5.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 495 degrees Celsius 120 minutes.*

Results:

**Colour:** A pale mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk colour gaffer glass.

**Shape:** The shapes of the murrine have been affected by the length of time for heat development in that their opaque outer casing looks softer and rounder.

**Group 6.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 505 degrees Celsius 120 minutes.*

**Results:**

**Colour:** A pale reddish mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk colour gaffer glass.

**Shape:** The shapes of the murrine have been affected by the length of time for heat development in that the inner edges of the opaque buttermilk casing colour is starting to bleed into the photosensitive glass.

**Group 6.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 505 degrees Celsius 120 minutes.*

**Results:**

**Colour:** A pale reddish mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the length of time for heat development in that the inner edges of the opaque buttermilk casing colour is starting to bleed into the photosensitive glass.

**Group 6.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 505 degrees Celsius 120 minutes.*

**Results:**

**Colour:** A medium dark amethyst mauve colour in some murrine can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have become distorted by the length of time for heat development and the inner edges of the opaque buttermilk casing colour is starting to bleed into the photosensitive glass.

**Group 7.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 525 degrees Celsius 90 minutes.*

**Results:**

**Colour** A pale reddish mauve can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase of temperature of the heat development in that their edges appear to have softened while the square shapes remain and the inner edges of the opaque buttermilk casing colour is starting to bleed into the photosensitive glass.

**Group 7.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 525 degrees Celsius 90 minutes.*

**Results:**

**Colour:** Pale reddish mauve can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase of temperature of the heat development in that their edges appear to have softened and started to become round and the inner edges of the opaque buttermilk casing colour is starting to bleed into the photosensitive glass.

**Figure 55**

**Photosensitive glass murrine: Comparative ultraviolet light exposure results.**

		
<p><b>Group 4.1:</b> UV exposure: 10 minutes Heat development: 120 mins @ 490 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 120 mins @ 490 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 120 mins @490 degrees Celsius.</p>
		
<p><b>Group 5.1:</b> UV exposure: 10 minutes Heat development: 120 mins @ 495 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 120 mins @ 495 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 120 mins @ 495 degrees Celsius.</p>
		
<p><b>Group 6.1:</b> UV exposure: 10 minutes Heat development: 120 mins @505 degrees Celsius</p>	<p>UV exposure: 20 minutes Heat development: 120 mins @505 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 120 mins @ 505 degrees Celsius.</p>

**Group 7.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 525 degrees Celsius 90 minutes.*

**Results:**

**Colour** A red with a small tinge of purple colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass. This colour development is caused by the length of time exposed to ultra violet light as well as the temperature for heat development.

**Shape:** The shapes of the murrine have been affected by the increase of temperature of the heat development in that their edges appear to have softened and started to become round and the inner edges of the opaque buttermilk casing colour appears to be moving into the photosensitive glass.

**Group 8.1:**

*Ultra violet light exposure for ten, twenty and thirty minutes.*

*Heat development temperature @ 550 degrees Celsius 90 minutes.*

**Results:**

**Colour** A pale pink mauve colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase of temperature of the heat development in that their edges appear to have softened into round shapes and the inner edges of the opaque buttermilk casing colour is starting to flow over the photosensitive glass.

**Group 8.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 550 degrees Celsius 90 minutes.*

**Results:**

**Colour** A medium dull red colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature of heat development in that their edges appear to have softened into distorted round shapes and the inner edges of the opaque buttermilk casing colour is starting to cover over the photosensitive glass.

**Group 8.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 550 degrees Celsius 90 minutes.*

**Results:**

**Colour** A red with a little purple colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature of heat development in that their edges appear to have become distorted round shapes and the inner edges of the opaque buttermilk casing colour is starting to move over the photosensitive glass.

**Group 9.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 575 degrees Celsius 90 minutes.*

**Results:**

**Colour** A red with a little purple colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been melted together caused by the increase the temperature. Their edges appear to have become distorted molten shapes with the outer casing and the photosensitive glass mixing.

**Group 9.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 575 degrees Celsius 90 minutes.*

**Results:**

**Colour** A red colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass that appears to be crawling or beading over the red colour.

**Shape:** Some shapes of the murrine have been melted together caused by the increase the temperature. Their edges appear to have become round and bead-like.

**Group 9.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature 575 degrees Celsius 90 minutes.*

**Results:**

**Colour** A red colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been melted together caused by the increase the temperature during heat development. Their edges appear to have become distorted molten shapes with the outer casing and the photosensitive glass mixing.

**Figure 56**

**Photosensitive glass murrine:** Comparative ultraviolet light exposure results.

		
<p><b>Group 7.1:</b> UV exposure: 10 minutes Heat development: 90 mins @ 525 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 90 mins @ 525 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 90 mins @ 525 degrees Celsius.</p>
		
<p><b>Group 8.1:</b> UV exposure: 10 minutes Heat development: 90 mins @ 550 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 90 mins @ 550 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 90 mins @ 550 degrees Celsius.</p>
		
<p><b>Group 9.1:</b> UV exposure: 10 minutes Heat development: 90 mins @575 degrees Celsius</p>	<p>UV exposure: 20 minutes Heat development: 90 mins @575 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heath development: 90 mins @ 575 degrees Celsius.</p>

**Group 10.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 525 degrees Celsius 120 minutes.*

**Results:**

**Colour** A medium dull red colour with a tinge of purple can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature for heat development. The square shapes have softened and distorted and the inner edges of the opaque buttermilk casing colour is starting to flow into the photosensitive glass.

**Group 10.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 525 degrees Celsius 120 minutes.*

**Results:**

**Colour** A medium shade puce red colour with a tinge of purple can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature for heat development. The original square shapes have softened and distorted and the inner edges of the opaque buttermilk casing colour is starting to bleed into the photosensitive glass.

**Group 10.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 525 degrees Celsius 120 minutes.*

**Results:**

**Colour** A red colour can be seen in the photosensitive glass component of the murrine surrounded by a casing of opaque buttermilk coloured gaffer glass. Some murrine have a casing of yellow/orange gaffer glass.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature for heat development. The original square shapes have softened and distorted and some have beaded together. All the inner edges of the opaque buttermilk casing colour is starting to move over the top of the photosensitive glass area.

**Group 11.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 550 degrees Celsius 120 minutes.*

**Results:**

**Colour:** The casing of opaque buttermilk coloured gaffer glass and yellow/orange has covered surface of the murrine.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature as well as the length of time for heat development. The original shapes have beaded and distorted and some have stuck together.

**Group 11.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 550 degrees Celsius 120 minutes.*

**Results:**

**Colour:** The casing of opaque buttermilk coloured gaffer glass has covered nearly all the surface of the murrine. A very small amount of red colour can be seen.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature as well as the length of time for heat development. The original shapes have beaded and distorted and some have stuck together.

**Group 11.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 550 degrees Celsius 120 minutes.*

**Results:**

**Colour:** The casing of opaque buttermilk coloured gaffer glass has covered most of the surface of the red coloured murrine.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature as well as the length of time for heat development. The original shapes have become rounded.

**Group 12.1:**

*Ultra violet light exposure for ten minutes.*

*Heat development temperature @ 575 degrees Celsius 120 minutes.*

**Results:**

**Colour:** The casing of opaque buttermilk coloured gaffer glass has covered most of the surface of the red coloured murrine.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature as well as the length of time for heat development. The original shapes have become rounded.

**Group 12.2:**

*Ultra violet light exposure for twenty minutes.*

*Heat development temperature @ 575 degrees Celsius 120 minutes.*

**Results:**

**Colour:** The casing of opaque buttermilk coloured gaffer glass has melted into the photosensitive glass component of the red murrine surface .Many of the murrine have stuck to one another.

**Shape:** The shapes of the murrine have been affected by the increase in the temperature as well as the length of time for heat development. The original shapes have become irregular and some what distorted.

**Group 12.3:**

*Ultra violet light exposure for thirty minutes.*

*Heat development temperature @ 575 degrees Celsius 120 minutes.*

**Results:**

**Colour:** The casing of opaque buttermilk coloured gaffer glass has covered most of the surface of some of the red coloured murrine.

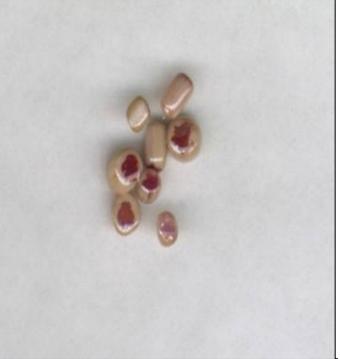
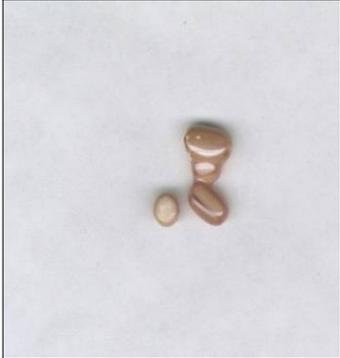
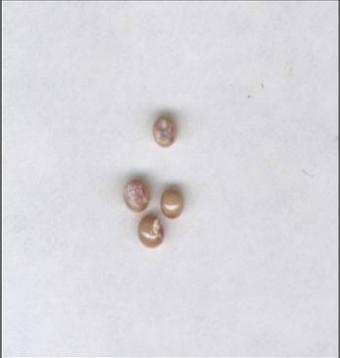
**Shape:** The shapes of the murrine have been affected by the increase in the temperature as well as the length of time for heat development. The original shapes have become rounded or oval.

**Overview and outcome of the experimentation**

The results of the twelve groups were positive and these twelve graded tonal coloured photosensitive glass murrine groups can now be used as a reference base for future photosensitive murrine glass art-works. However, colour development comparisons of exposure times under ultraviolet light and heat development times in an electric kiln should always be made, because different electric kilns will produce slightly different colour results due to their temperature calibration. This fact is important to note when applying these experimental results to any future designs involving photosensitive glass murrine or mosaics.

**Figure 57**

**Photosensitive glass murrine: Comparative ultraviolet light exposure results.**

		
<p><b>Group 10.1:</b> UV exposure: 10 minutes Heat development: 120 mins @ 525 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 120 mins @ 525 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 120 mins @ 525 degrees Celsius.</p>
		
<p><b>Group 11.1:</b> UV exposure: 10 minutes Heat development: 120 mins @ 550 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 120 mins @ 550 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 120 mins @ 550 degrees Celsius.</p>
		
<p><b>Group 12.1:</b> UV exposure: 10 minutes Heat development: 120 mins @ 575 degrees Celsius.</p>	<p>UV exposure: 20 minutes Heat development: 120 mins @ 575 degrees Celsius.</p>	<p>UV exposure: 30 minutes Heat development: 120 mins @ 575 degrees Celsius.</p>

## **Methods and procedures for collecting data**

### **Data sources**

My data sources were gathered from the results of the twelve graded tonal coloured photosensitive glass murrine groups. There were thirty six murrine experiments in total.

### **Data collection**

The results of the thirty six murrine experiments were digitally scanned and photographed for my data collection. The scanned results formed my primary source materials.

### **Data presentation issues**

The question of how I was going to present the thirty six murrine experiments was an issue because the murrine looked much smaller than they actually were when printed on paper.

### **Presentation analysis**

The thirty six murrine experiments were stored on a compact disk as well as being printed in hard copy format in a photographic table. Each murrine experiment was placed in a small plastic sleeve with ultra violet light exposure, heat and development temperature and the length of time it took for the experiment was noted.

### **Analysis of the data**

The data were analysed according to their colour development which was based on exposure to ultraviolet light and timed heat development based on 490, 495, 505, 525, 550 and 575 degrees Celsius.

### **Interpretation analysis of my collected data**

Visual colour comparisons were made of timed exposure, timed heat development and the time it took to for the experiments to mature in the kiln were taken into consideration when interpreting the results of the data.

### **Criteria for the interpretation of the data results**

The criteria for the interpretation of the systematic experimental results were that twelve groups composed of thirty six murrine experiments were made. Each group contained three experiments with increasing ultraviolet light exposure. In all the three experiments belonging to the group, the timed heat development temperatures remained the same. An experimental journal was kept to record the experiments as they were made.

### **Potential application**

My vision for the potential future use of photosensitive glass murrine or mosaics is that before exposure to ultraviolet light the murrine or mosaics are placed in a mould and glued into position. After ultraviolet light exposure (using a photographic image or a mask) the mould containing the murrine or mosaics is then heat developed using a timed temperature control following a casting/slumping or fusing schedule (Klein & Ward 1992, 22). The ultraviolet light exposure process bypasses the need to use various coloured murrine to make up a design. Cast vessels in mosaic glass imitating the Arretine pottery of the late first century BC/early first century AD are another example where photosensitive glass murrine/mosaics can be substituted for coloured glass mosaics/murrine (Klein & Ward 1992, 24). Photosensitive glass murrine can be used as decorative motifs of various colours on the same art piece when glued to blown ware then exposed to ultraviolet light before timed heat development. Among the more popular blown decorated wares of the first century AD were the '*splashed*' vessels adorned with blobs of different coloured glass (Klein and Ward 1992, 27). Photosensitive glass murrine could be substituted for the different splashed colours provided the ultraviolet exposure of the murrine colour development was based on a heat and time development temperature that insured the murrine melting into the surface of the glass of the vessel. A mould can also be used to achieve similar results.

### **Application of the results**

To apply the colour results shown on each photosensitive murrine set it is important to compare the colours of ultraviolet light exposure times at specific heat development times for certain periods of time before deciding on the glass technique to be used such as 'fusing', 'slumping'. If the glass piece is required to remain as it was, then note the development temperatures and corresponding colour exposures and the time it took to develop the desired colours. Too long a period at heat development may result in the desired colour but will cause the piece to distort. Suit the depth of colour to the length of time to preserve the shape and integrity of the glass piece.

Case Study Three:  
Sub-category 5.3.1.  
Bead-making.



*UV exposure: 40 minutes, Heat development: @525 degrees Celsius  
Time: 181 minutes.*

### **5.3.0. Case Study Three: Bead-making/Flameworking (Hot glass)**

#### **Sub-category 5.3.1: Bead-making**

Based on the outcomes of the successful scoping bead-making experiments, a series of further experiments, using Spectrum #96 White Opalescent canes and medium to large chips sizes of photosensitive glass were completed.

### **6.1.0c. Systematic Experimentation**

The systematic experiments in this case study sub-category consisted of eight groups of twelve differently shaped photosensitive glass beads that were made using a bead-making torch at a bench.

#### **Technical process**

Heat development firing schedules that were used for each group can be viewed on the pages following the illustrated experimental results.

#### **Technical equipment**

A propane gas and oxygen 'Hot-head' or bead making torch was used to melt the cane onto the mandrel which was then rolled twice into the photosensitive glass chips.

#### **Method: Exposing the groups of beads under UV light.**

A method of exposure on a rotating turntable under ultraviolet in the light box from ten to fifty minutes was selected for each group of beads after the beads had been annealed.

**Process details** of the method and experimental process for this case study can be seen in Appendix Ciii(a) (Chapter Six) Case study Three, sub category 5.3.1. Bead-making.

### **Bead-making Experiments**

The following experiments consisted of a control group of beads and seven groups of timed heat development temperatures that had been exposed to ultraviolet light from ten minutes to ninety minutes.

**Group b: Control Group** of twelve individually shaped photosensitive glass beads

*Ultra violet light exposure: Nil.*

*Heat development temperature @ 600 degrees Celsius for 181 minutes.*

**Results:**

**Colour:** A mottled tinge of pale pink on all the beads.

**Shape:** No alteration of shape was visible.

**Group c:**

*Ultra violet light exposure from ten to ninety minutes.*

*Heat development @ 495 degrees Celsius for 181 minutes.*

**Results:**

**Colour** Mottled pink/light reds and dark reds on the opal white base from ten to sixty minutes. Darker reds can be seen from seventy to ninety minutes.

**Shape:** The shapes of the beads were not altered by the low heat development temperature.

**Group d:**

*Ultra violet light exposure from ten to ninety minutes.*

*Heat development @ 505 degrees Celsius for 181 minutes.*

**Results:**

**Colour:** There is some evidence of a mauve colour appearing amongst the mottled pink/light reds and dark reds on the opal white base from ten to thirty-five minutes. The most interesting colour development consisting of pale pink, mauve, bright red, dark ruby red and wine red appeared on the bead exposed to ultraviolet

light for forty minutes. Darker reds mixed in with bright reds and pinks can be seen from seventy to ninety minutes

**Shape:** The shapes of the beads have not been altered by the low heat development temperature.

**Group e:** *Ultra violet light exposure from ten to ninety minutes.*

*Heat development @ 525 degrees Celsius for 181 minutes.*

**Results:**

**Colour:** Evidence of mauves between the mottled pink, bright red and dark red can be seen from ten minutes to thirty-five minutes. Wine reds with mauve halos can be seen amongst the mottled mauves, pinks and bright reds from fifty minutes to ninety minutes. The bead exposed under ultraviolet light for forty minutes shows good clear wine red colours with mauve halos. Bright clear reds are adjacent to bluish mauves and pinks on a white background. This bead has a good colour development potential.

**Shape:** The shapes of the beads have not been altered by the low heat development temperature.

**Group f:**

*Ultra violet light exposure from ten to ninety minutes.*

*Heat development temperature @ 550 degrees Celsius for 181 minutes.*

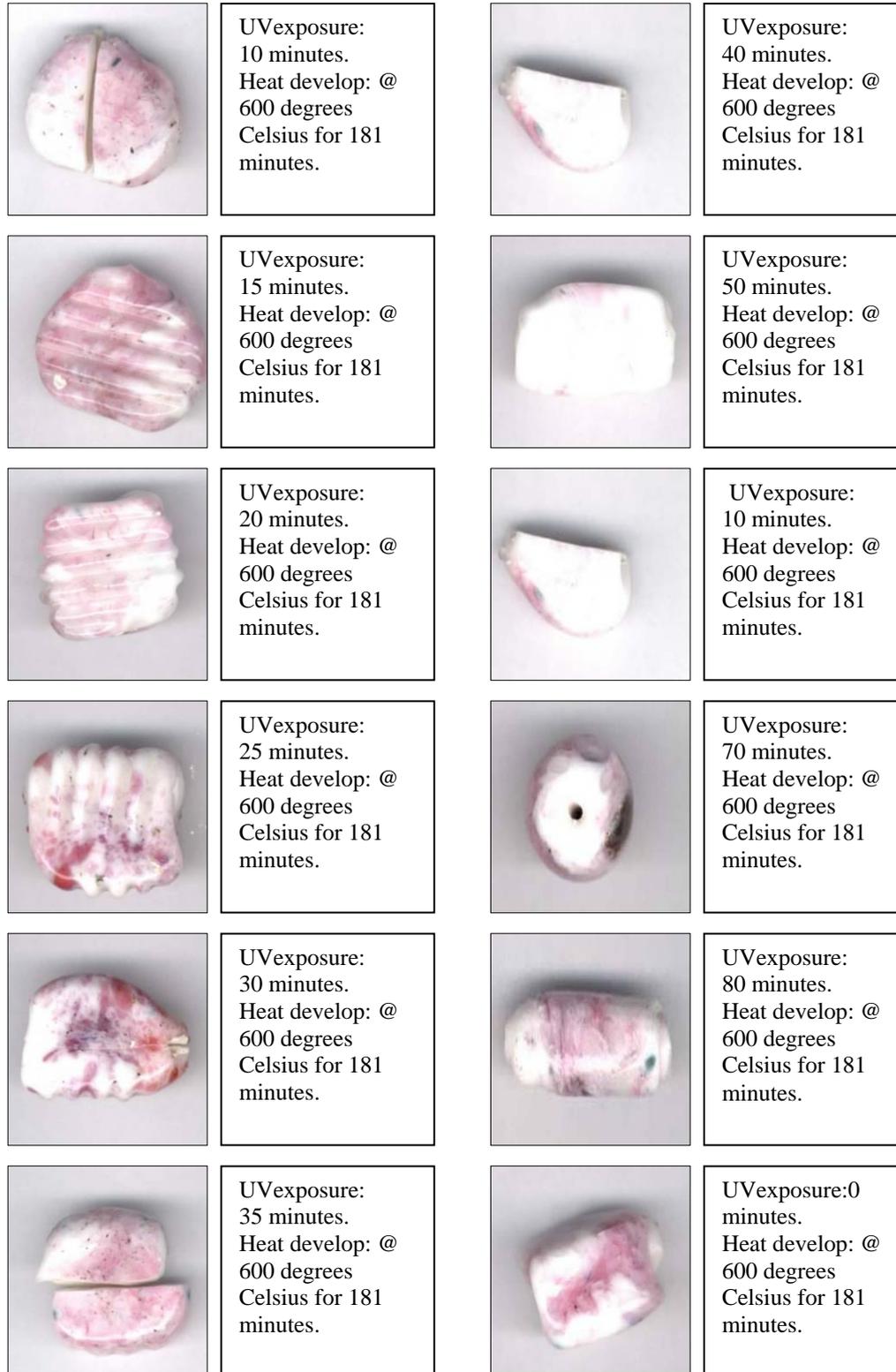
**Results:**

**Colour:** Some mauves can be seen together with the pinks, light reds and dark wine reds on a white background from ten to thirty-five minutes. Bright reds are mingled with dark wine reds from forty minutes to ninety minutes. The colours on the beads from ten minutes to twenty-five have a streaky appearance. The three beads at thirty, thirty-five and forty minutes have retained their mottled appearance

**Shape:** The shapes of the beads have not been altered by the medium heat development temperature.

**Figure 58**

**Control group b Experiment: Bead-making using photosensitive glass chips.**



**Figure 59**

**Group c Experiment: Bead-making using photosensitive glass chips.**



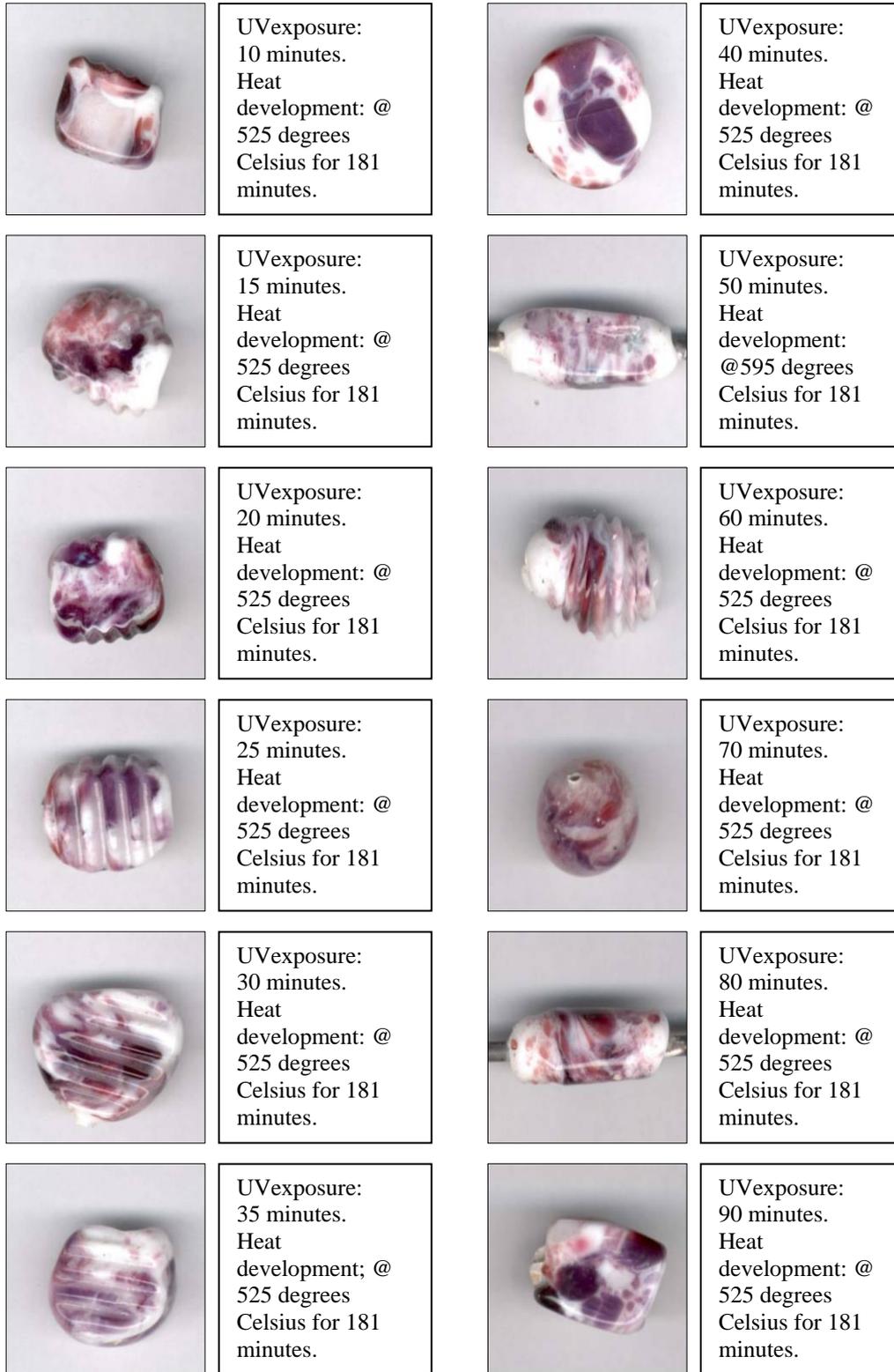
**Figure 60**

**Group d Experiment:** Bead-making using photosensitive glass chips.



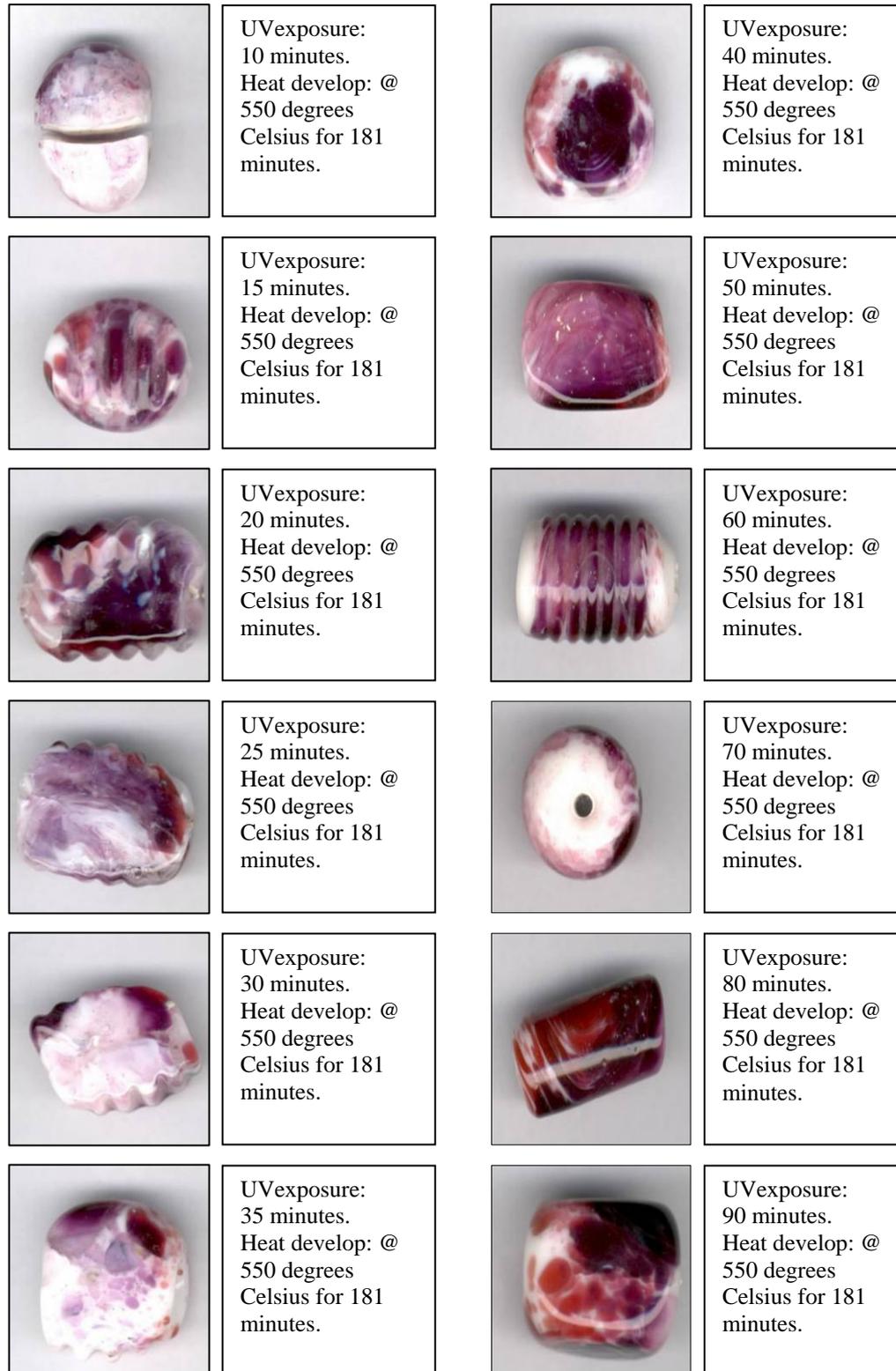
**Figure 61**

**Group e Experiment: Bead-making using photosensitive glass chips.**



**Figure 62**

**Group f Experiment: Bead-making using photosensitive glass chips.**



**Group g:**

*Ultra violet light exposure from ten to ninety minutes.*

*Heat development temperature @ 575 degrees Celsius for 181 minutes.*

**Results:**

**Colour** Darker mauves can be seen to be merging with the mottled pinks, light reds and dark wine reds on a white background from ten to twenty-five minutes. At thirty to forty minutes the mauves have disappeared and clearly defined bright mottled reds can be seen adjacent to wine reds on a white background. Mottled bright reds are mingled with mottled dark wine reds from fifty minutes to ninety minutes. Beads fired at this high temperature show good mottled clear isolated colour development potential.

**Shape:** The shapes of the beads have not been altered by the high heat development but signs of softening on some of the ridges on some beads are evident.

**Group h:**

*Ultra violet light exposure from ten to ninety minutes.*

*Heat development temperature @ 600 degrees Celsius for 181 minutes.*

**Results:**

**Colour:** Darker mauves are streaked within the mottled pinks, light reds and dark wine reds on a white background from ten to twenty-five minutes. At thirty to thirty-five minutes the mauves and reds have a streaked appearance. Bright mottled reds and streaky mauves can be seen adjacent to wine reds on a white background from forty minutes to ninety minutes. The beads fired at this high temperature show an interesting colour development potential.

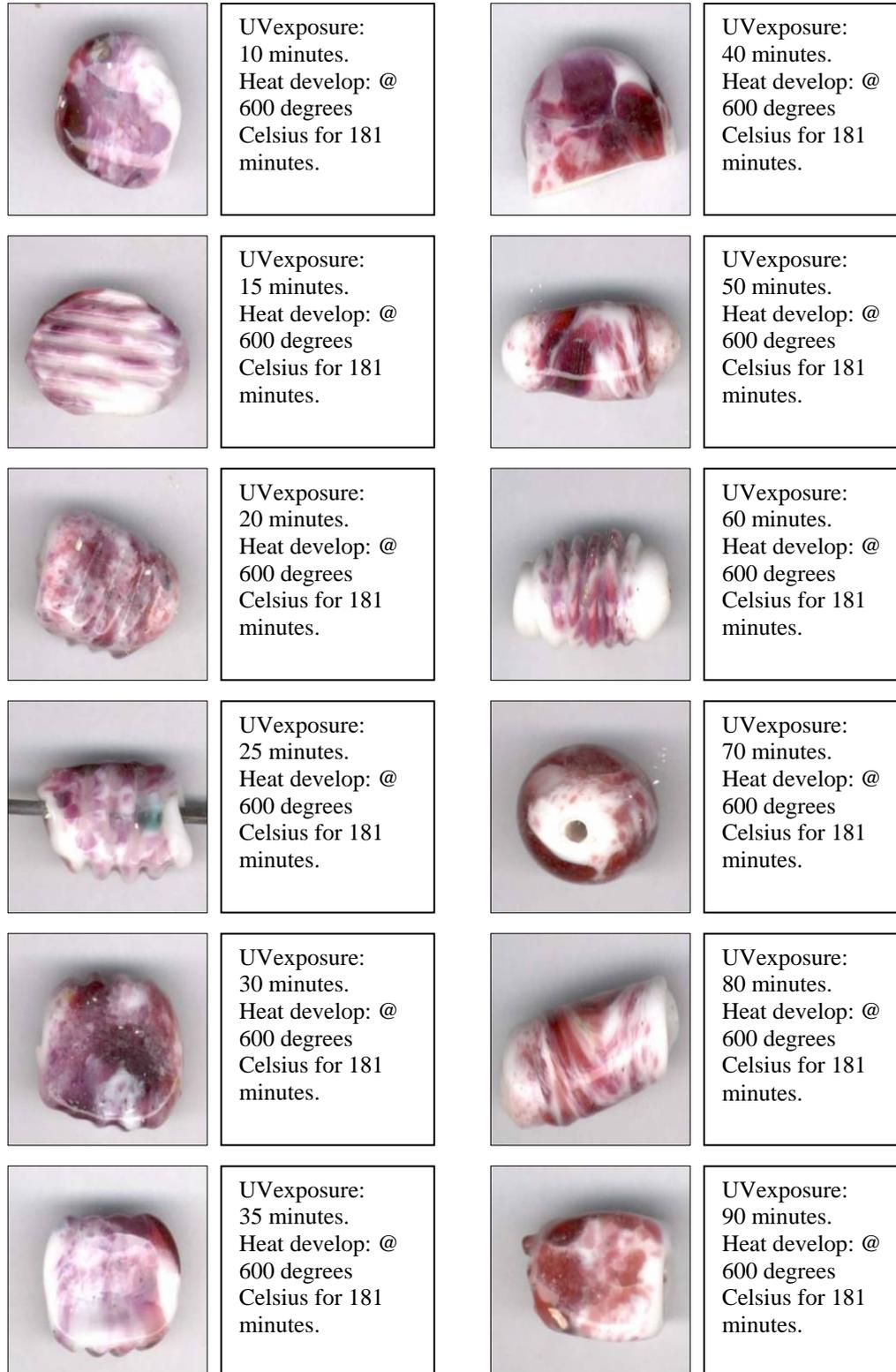
**Figure 63**

**Group g Experiment: Bead-making using photosensitive glass chips.**

	UVexposure: 10 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.		UVexposure: 40 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.
	UVexposure: 15 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.		UVexposure: 50 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.
	UVexposure: 20 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.		UVexposure: 60 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.
	UVexposure: 25 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.		UVexposure: 70 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.
	UVexposure: 30 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.		UVexposure: 80 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.
	UVexposure: 35 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.		UVexposure: 90 minutes. Heat develop: @ 575 degrees Celsius for 181 minutes.

**Figure 64**

**Group h Experiment: Bead-making using photosensitive glass chips.**



**Group i:**

*Ultra violet light exposure from ten to ninety minutes.*

*Heat development temperature @ 625 degrees Celsius for 181 minutes.*

**Results:**

**Colour** The mauves are streaked within the mottled pinks and light reds from ten minutes to 30 minutes giving the bead a muddy appearance. Dark wine reds and bright reds start to appear at thirty-five minutes and no mauves were seen to be present. At forty minutes to ninety the only colours that can be seen are mottled clear bright reds and dark wine reds on a white background

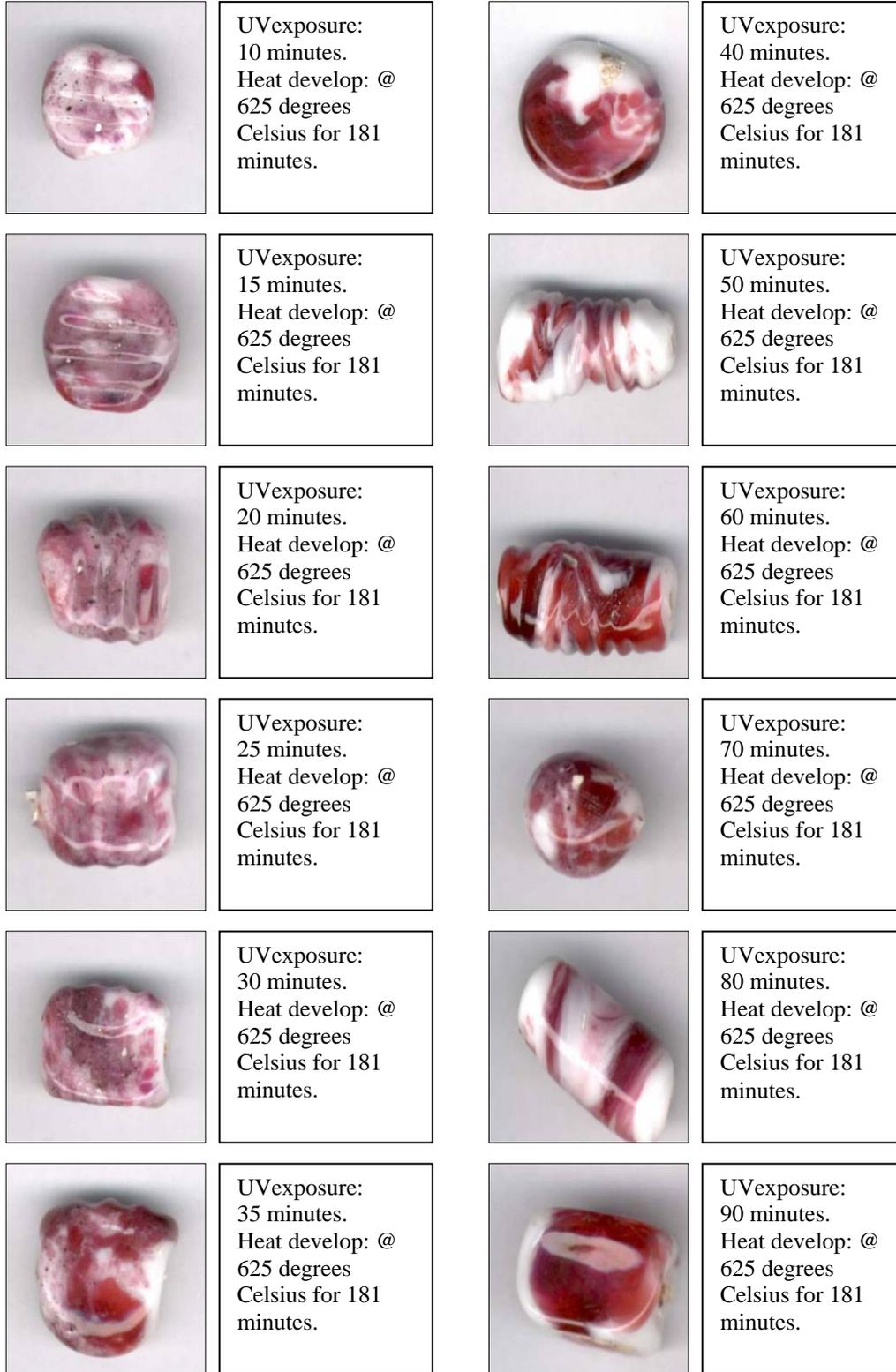
The beads fired at this high temperature show an interesting mauve, pink bright red and wine red colour development at the shorter ultraviolet exposure times and clear bright reds that intermingle with patches of dark wine reds at the longer exposure times. Heat development at this high temperature shows a domination of clear bright reds and dark wine reds with defined edges.

**Overview and outcome of the experimentation**

All the beads were put through an annealing cycle in kiln as soon as they were completed and taken away from the naked flame of the torch before exposing them to ultraviolet light. This was achieved by placing the bead into a preheated kiln at approximately 530 degree Celsius (985 degrees Fahrenheit). The beads remained in the annealing kiln for about seven to eight hours which was then switched off and left overnight. The annealing process eliminates any stresses in the glass bead to give it a more stable condition.

**Figure 65**

**Group i Experiment: Bead-making using photosensitive glass chips.**



This systematic experimentation for the incorporation of photosensitive glass into the ancient traditional technique of bead-making consisted of eight groups of graded tonal coloured photosensitive glass beads. The results of the eight groups were positive and these eight graded tonal coloured photosensitive glass bead groups can now be used as a reference base for future photosensitive glass artworks. However, colour development comparisons of exposure times under ultraviolet light and heat development times in an electric kiln should always be made, because different electric kilns will produce slightly different colour results due to their temperature calibration. This fact is important to note when applying these experimental results to any future designs involving photosensitive glass beads.

#### **Methods and procedures for collecting data for this sub-category**

The scanned results and photographs of the beads were my primary source materials. Secondary source materials such as diagrams of the outline of each bead enabled me to recognize each bead according to its intended ultraviolet light exposure. This recognition was important as it was based on touch recognition under dark conditions.

#### **Data presentation issues**

The issue of presenting the data for this research thesis was dealt with by printing out the scanned results of the ninety-six bead experiments and placing these results in a visual comparative colour development data table based on colour and distortion to heat development.

**Figure 66**

**Comparative colour development bead-making data table:** Bead-making using photosensitive glass chips.

**Case Study Three: Bead making/Flame working.**  
*Sub category 1: Photosensitive beads made with Gaffer#080 Photosensitive glass and Spectrum #96 opaque white canes using a Bead-making torch.*

**Photosensitive glass beads comparative colour development data**

Control shapes of beads b	Ultra violet light exposure times	Heat development temperatures in degrees Celsius.							@ mins
		495 c	505 d	525 e	550 f	575 g	600 h	625 i	
	10 mins								181
	15 mins								181
	20 mins								181
	25 mins								181
	30 mins								181
	35 mins								181
	40 mins								181
	50 mins								181
	60 mins								181
	70 mins								181
	80 mins								181
	90 mins								181

## **Conclusion**

The photosensitive glass bead experiments indicate that heat development at temperatures from 600 degrees Celsius and above show that the incorporated photosensitive glass will mainly consist of areas of bright red to dark red in the white bead after ultraviolet light exposure from 40 minutes to 90 minutes. Beads heat developed at the medium temperatures of 525, 550 and 575 degrees Celsius show that the incorporated photosensitive glass show areas of mauves, dark purple, light red and dark red. Beads heat developed at the lower temperatures of 505 degrees Celsius show pale mauve, purple and light puce before ultraviolet light exposure at 35 minutes. At 40 minutes the colours become darker puce, darker mauve, purple and finally light red at 90 minutes. The beads heat developed at 495 degrees Celsius started off with pale pinks to mauves and very light reds in the white body. The intensity of the colours depends upon the length of ultraviolet light exposure to the bead.

## **Potential applications**

Bead-making, especially beads made using a torch has become very popular mainly because of the availability of materials and inexpensive equipment. The bead making experimental results as shown in the data table can be applied to making buttons, sub-category 5.3.2 of this case study.

The potential of using photosensitive glass in the bead-making process as discussed in the results of the experiments depends on the colours desired in the bead. As seen from the experimental results colours in the beads depend upon timed exposure to ultraviolet light, heat developments times and temperatures. Using photosensitive glass on its own or with a variable glass cane such Spectrum #96 which is compatible with photosensitive glass, cuts down the expense of having to have a stock of coloured glass canes at hand. The random mottled results show a new and different potential for bead and button making.

### **Applying the data table results to a prototype**

To apply the data results to a prototype, the glass artist needs to select a colour result from one of the seven groups of photosensitive beads. For example, the bead at the 40 minute ultraviolet light exposure, with a heat development temperature at 525 degrees Celsius, group e has the most potential for developing a range of colours.

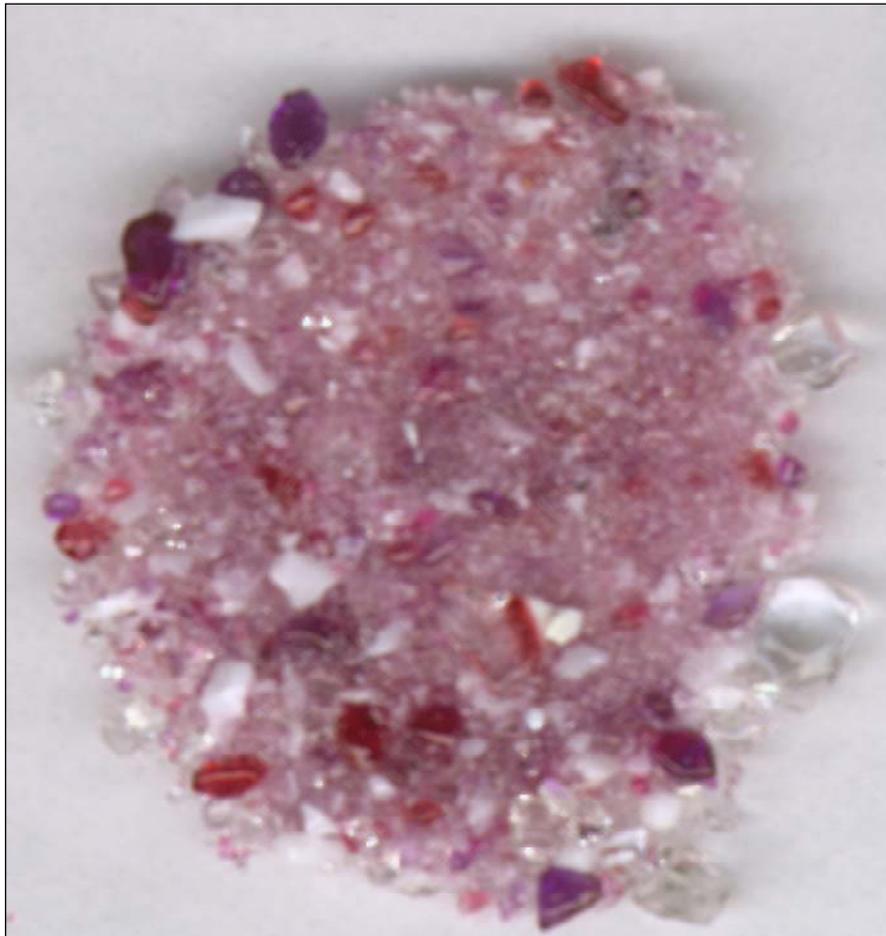
### **Overview**

My objective of incorporating photosensitive glass into the traditional bead making technique has been met and can be considered successful contribution to the ancient technique.

### **Suggested decorative applications**

Amazing affects can be achieved with an inclusion of fine silver wire to the bead at the photosensitive chip rolling stage. Leaves or foils of silver, gold, palladium and copper can also be added to the bead at the photosensitive chip rolling stage. Beads can be sandblasted for interesting effects. Fuming is a technique borrowed from ceramic that has been developed in the past fifteen years for making glass beads. Fuming consists of heating silver or gold in the flame, so that the metals vaporize or 'fume' microscopically thin layers of particles onto the glass bead. These particles stick to the hot glass surface changing its colour with interesting effects. Silver turns clear glass into a yellowish colour, giving shades of blue and greens when backed with a dark colour. Gold turns clear glass shades of pinks and reds. The precious metal coating becomes increasingly visible the more the glass is fumed. I suggest that the fuming technique can commence at the rolling of the molten bead base into photosensitive glass chips stage (Allan L.2006).

Case Study Four:  
Sub-category 5.4.2.  
Pate de Verre Triaxial Blends.



*Triaxial blend disk Eight: Ultraviolet light exposure: 10 minutes.  
Heat development @ 495 degrees Celsius for 120 minutes.*

#### **5.4.0. Case Study Four. Kiln casting/Kiln formed glass (Warm glass)**

**Sub-category 5.4.2:** Simple open face kiln forming.

My decision to use the diagrammatic ternary system or triaxial blending system as a method of studying the amalgamation effects of three materials being blended was based on the four successful scoping experiments that are described in Chapter Five of this thesis. Therefore, the outcome of this experimental research that concentrated on examining and documenting the photosensitive glass triaxial experiments as a case study of materials research for art practice can be considered an original contribution to the discipline. The report is printed in full here as triaxials are new to the thesis.

#### ***Structure***

##### **6.1.0c. Systematic experimentation**

A Line-blend involves two mixtures and is simpler than a triaxial blend of three mixtures. Line blends are more suitable being applied to simple glass making procedures such as stringer pulling, rod making and murrine making.

Triaxial blends are used when a researcher wishes to explore the blended results of more than two mixtures. Colour variations involving the three crushed glasses were a good basis for continued experimentation and give more visual control.

#### **Objectives**

My objectives were to adapt the ceramic triaxial blending technology to a glass triaxial technology. The potential significance of using this triaxial blending technology is that it has a systematic experimental approach. Fournier (1992, 292) claimed that it was one way of enabling the study of the effects of various percentage combinations of the three crushed glasses as well as illustrating two line blends in the same test.

### **Technical process**

Grains of photosensitive glass, clear soda lime glass and opaque opal white Gaffer glass #101 were crushed separately, ready for blending. Crushed, blown photosensitive glass rods were combined with two unblown glass rods according to the percentages as set out in the selected triaxial blending diagram. The size of the crushed glass particles was based on a variety of sugar crystals in scoping experiment A: Comparisons of sugar granule crystal sizes with crushed opal white Gaffer glass#101. Case Study Two, sub-category 2: Pate de Verre. A mixture combination of half medium size of granules and half of fine sized granules of crushed glasses was selected in order to produce a disk texture that would resemble the sugar-like quality of traditional Pate de Verre. The triaxial blend percentage combinations of the three crushed percentage mixed glasses were initially exposed to ultraviolet light under controlled conditions before undergoing heat and time development in a digitally controlled electric kiln.

**Technical processes** that were applied can be seen in Appendix Civ (b) Case Study Four Chapter Six.

### **Glass Calculations**

The total gram amounts for the three glasses to be used in the Triaxial Blend Mixture were calculated for each triaxial blend experiment. These calculations can be seen in Appendix Civ(b) Case Study Four Chapter Six.

### **Method: Experimental glass adaptation to a Triaxial Blending method**

A Triaxial blend was made up using Gaffer Photosensitive Ruby Gold glass #080, Soda Lime furnace glass and Gaffer Opalescent White Glass #101. A tripple balance scale was used to calculate the exact amounts of sieved crushed glass needed. The selection of a twenty-one glass blend triaxial triangle rather than a six or ten blend triangle was made so that subtle changes showing a one fifth or twenty percent difference in the fraction of change could be observed.

The total gram amounts for the three glasses being used were calculated using <http://www.triaxialblend.com/CalculatorResults.aspx>

A Triaxial blend calculator is available @ <http://www.triaxialblend.com> and was a great help when computing the percentage of each glass tile.

A Triaxial blend printout sheet using [http://www.matric2000.co.nz/MatrixHelp/Blends\\_TriaxialBlends.htm](http://www.matric2000.co.nz/MatrixHelp/Blends_TriaxialBlends.htm) was created and proved to be time saving.

50 grams minimum for each glass material blend for each glass disk per triaxial blend was calculated.

Water to combine the glass ingredients would not be necessary but some type of liquid to bind the glass ingredients together after exposing each blend under ultraviolet light may be needed. Traditionally a light wall paper paste is often used when making Pate de Verre but I preferred to use a glass-binder such as 'Glastac' manufactured by BullsEye of Seattle, USA .

### **Glass Calculations**

The total gram amounts for the three glasses to be used in the Triaxial Blend Mixture were calculated to be the following for each triaxial blend experiment.

- Gaffer Photosensitive ruby glass #80 – 350 grams
- Clear used soda-lime glass from the furnace – 350 grams
- Gaffer Opalescent White #101 glass – 350 grams

The total of 1050 grams was divided by 21 tile tests allocating 50 grams of percentage blend mixture per tile.

- I decided to multiply 50 grams of 21 by 5 for each tile percentage blend requiring 250 grams for each tile packet.
- This calculation indicated that I would need 5251 grams of percentage mixture in total.

- 1750 grams for each glass.

I calculated that I would have to ‘*flame*’ approximately 2 kilos of photosensitive glass in the miniature furnace then crush it for the Triaxial Blend Percentage Mixture experiments.

Therefore 250 grams of the mixture for each tile packet would allow me to heat develop each mixture at five different temperatures such as 490, 495, 505, 525 and 550 degrees Celsius. The remaining 50 grams of this mixture would be held as an insurance against any mishaps.

### **Planning the construction/design of the firing schedules**

Firing schedules for four heat development temperatures of 495, 505, 525 and 550 degrees Celsius were designed for the heat development stage of these experiments.

### **Measuring my Independent variables and Dependent variables**

In these Pate de Verre Triaxial experiments, the independent variables are the exposure times to ultraviolet light of each blended disk, the heat development temperature that each disk was fired to in the electric kiln and the length or rate of time that the disk was held (soaked) for, the types of glass in the blend and finally the thickness of the blended Pate de Verre disks. The dependent variables are the colour and the intensity of the developed blended disks. It was necessary to define the basic variables then to only change one variable at a time in an experiment. To predict an outcome in experimental research, some variables are controlled and some are manipulated. Allison et al (1996, 7-29) define the dependent variable as the phenomenon that appears, disappears or changes and the independent variable is applied. After a few timed five minute experimental results were seen I came to the conclusion which was based on their sparse results, it would be more advantageous to try and change a variable to an additional timed development at 240 minutes for 5, 10, 20 and 30 minutes. This decision was followed by a further decision to alter a variable. It was to lower the heat development temperature to

490 degrees Celsius so that I could see whether any new colour developments would occur at the opposite end of the timed heat colour development.

### **Colour and heat development**

Colour development was achieved by timed exposure under ultra-violet light, followed by heating the ultraviolet light exposed photosensitive glass triaxial blends in an electric kiln at a defined temperature for a certain length of time.

### **The Triaxial Experiments**

Sixty one triaxial blending Pate de Verre experiments were made. The experiments were divided into three groups based on their colour results. Three control triaxial experiments were completed for each group. Colour coded tables were designed to illustrate the variety and depth of colours that were found within each disk of the triaxials. These colour coded results were cross referenced to show comparative results for the different temperatures as well as the different times they were fired at. Only the ultraviolet light exposures remained the same.

**Group 1** was divided into sections according to the length of time it took to develop the colours at the ultraviolet light exposure times of 5 minutes, 10 minutes, 20 minutes and 30 minutes at the heat development times of 90, 120, 180 and 240 minutes.

#### **Group 1:**

Temperature/Heat development range: 490,495 and 505 degrees Celsius.

Time taken for colour development: 90, 120, 180 and 240 minutes.

Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.

Control triaxial No.3. UV exposure: None. Heat development @ 505 degrees Celsius for 120 minutes.

**Figure 67**

**Control triaxial Group 1: plus Group 1: Section A.**

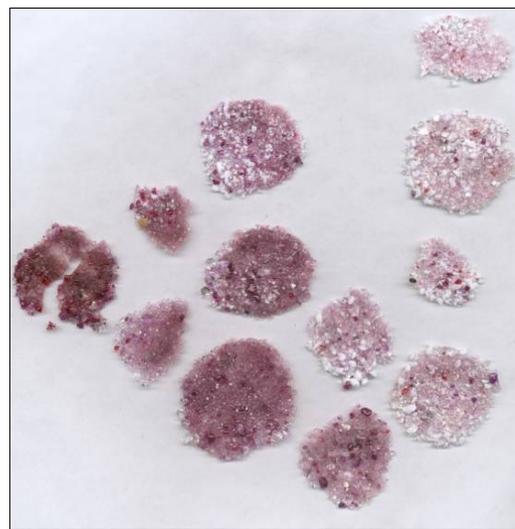
Temperature/Heat development range: @ 490 degrees Celsius.

Time taken for colour development: 90 minutes.

Ultraviolet light exposure range: 10, 20 and 30 minutes.



**Triaxial No.3, CONTROL** Group 1.  
UV exposure: Nil.  
Heat development: @ 505 degrees Celsius  
for 120 minutes.



**Triaxial No: 61.**  
UV exposure: 10 minutes  
Heat development: @ 490 degrees Celsius  
for 90 minutes

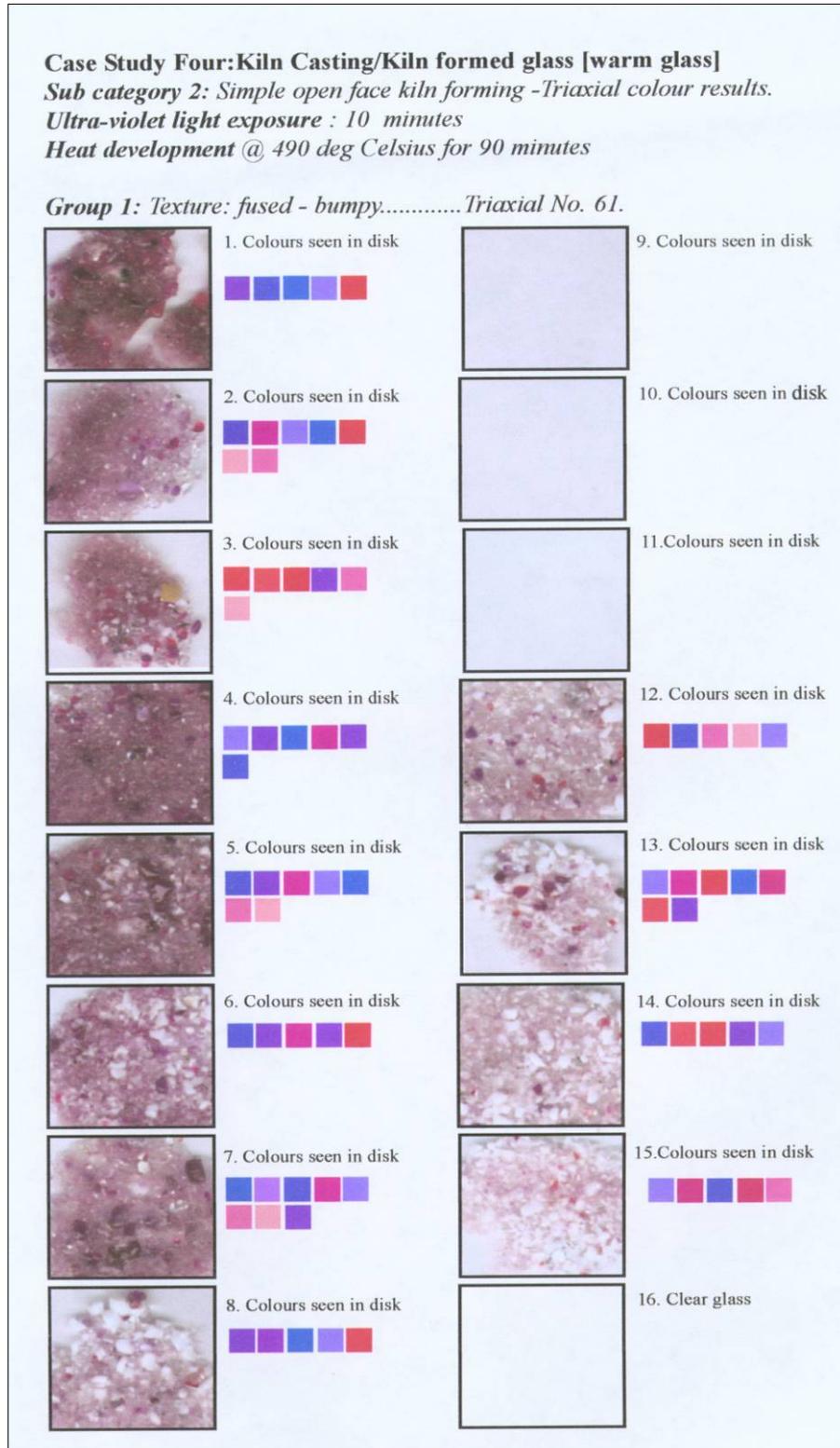


**Triaxial No: 60.**  
UV exposure: 20 minutes.  
Heat development: @ 490 degrees Celsius  
for 90 minutes.



**Triaxial No: 59.**  
UV exposure: 30 minutes.  
Heat development: @ 490 degrees Celsius  
For 90 minutes

**Figure 67a** (Triaxial No: 61)



**Figure 67b** (Triaxial No: 60)

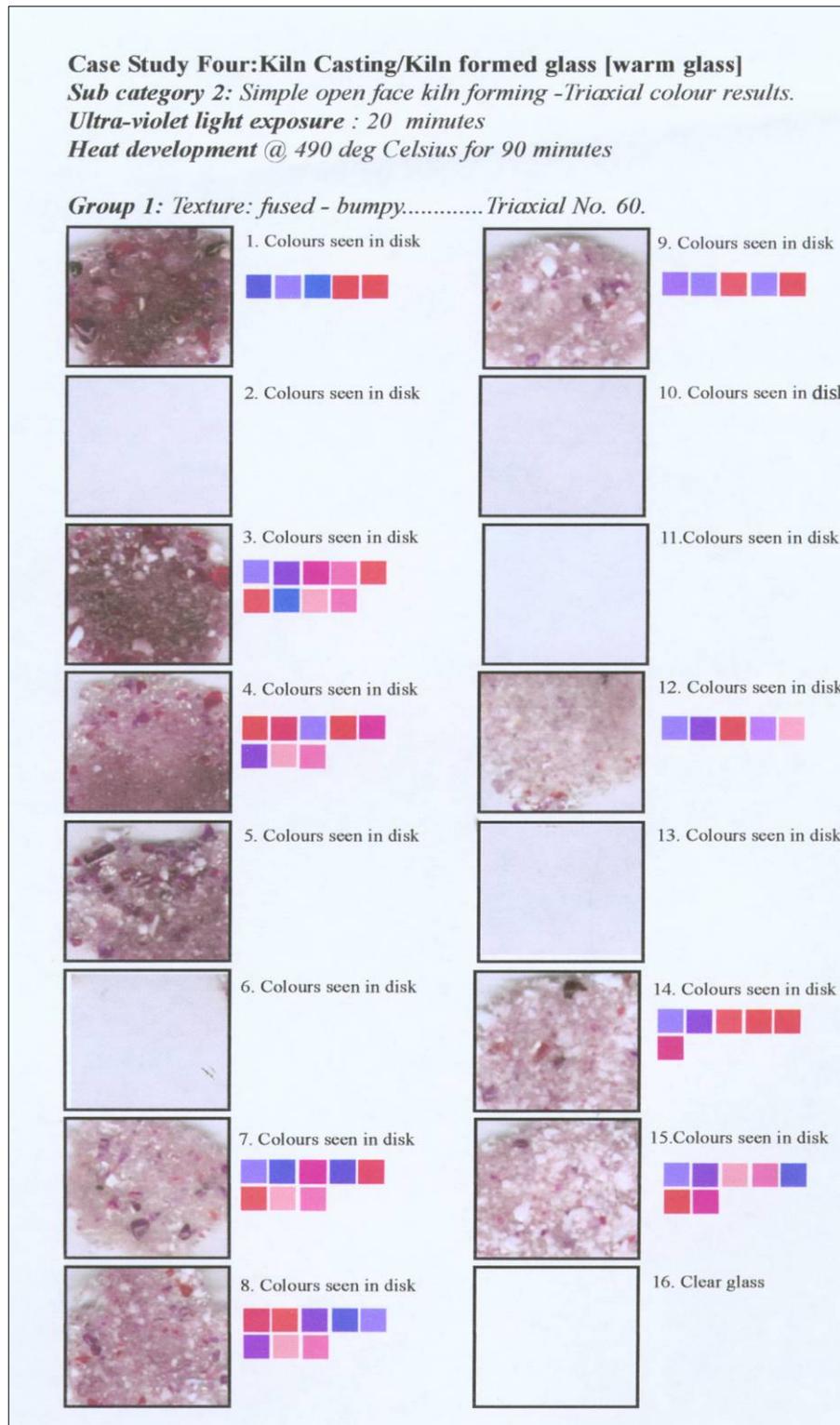
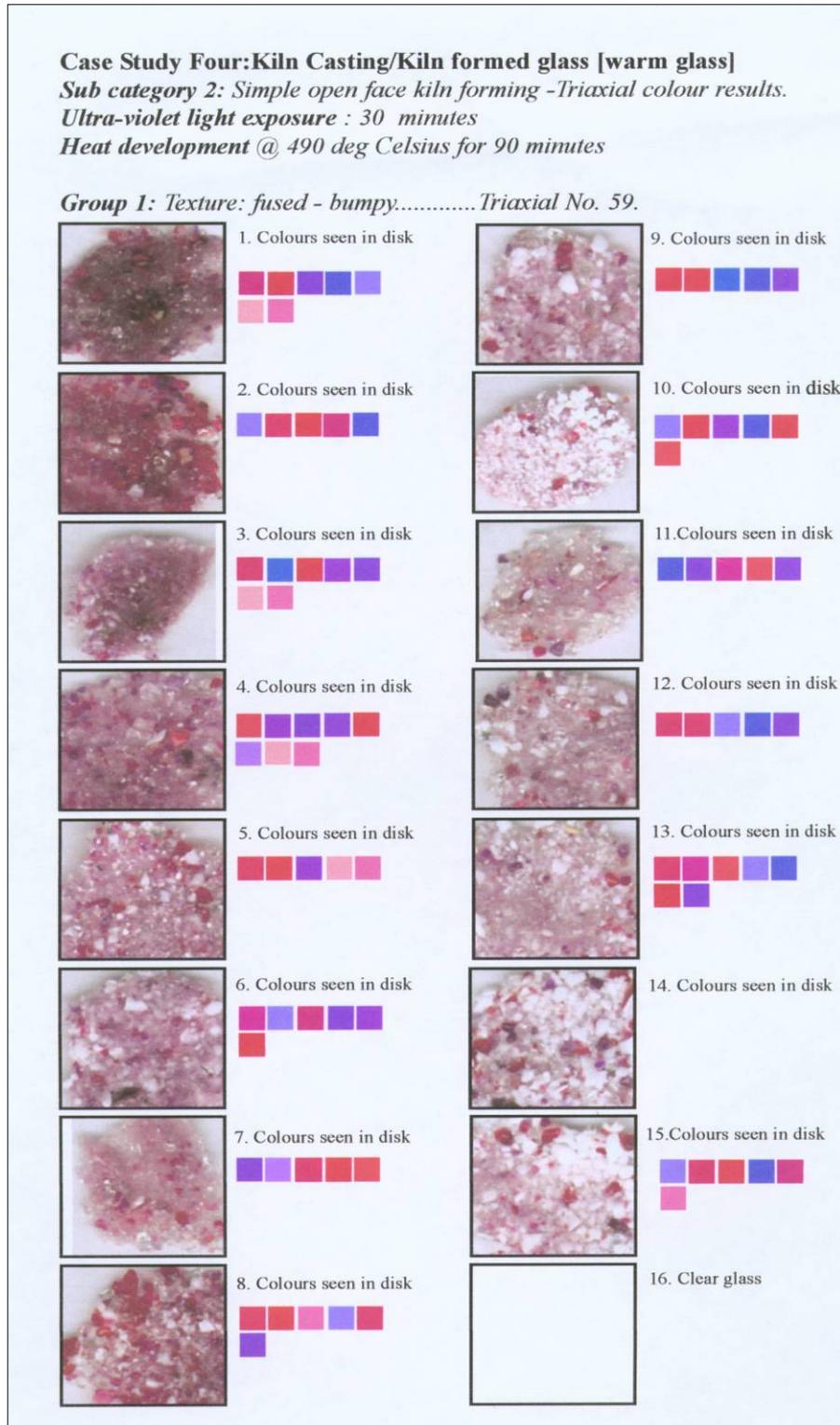


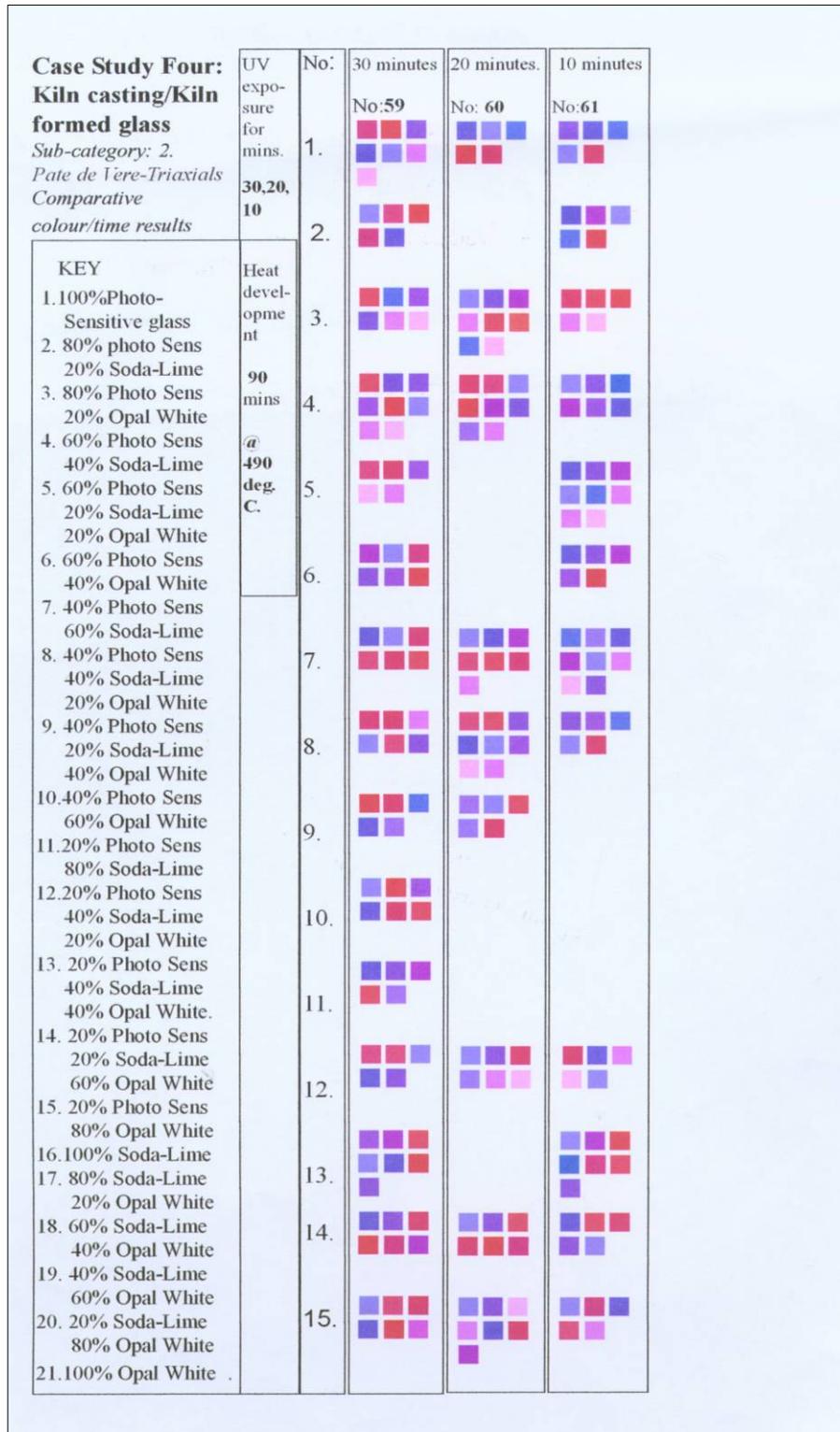
Figure 67c (Triaxial No: 59)



**Figure 67d** (Comparative timed UV exposure results)

<b>Case Study Four: Kiln Formed Photosensitive glass</b>  <i>Sub-category 1: Pate de Verre Triaxials Comparative UV Exposure Results</i>		Temp degrees Celsius	No:	Ultra violet light exposure times.				
				5 mins	10 mins	20 mins	30 mins	
<b>KEY</b> 1. 100%Photo-Sensitive glass 2. 80% photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White. 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		490	1.					
		490	2.					
		Heat development in minutes	90	3.				
			90	4.				
			90	5.				
			90	6.				
			90	7.				
			90	8.				
			90	9.				
			90	10.				
			90	11.				
			90	12.				
			90	13.				
			90	14.				
			90	15.				

Figure 67f (Comparative colour/time results)



**Analysis of Figures 67 (Group 1. A).**

**Section A: 490 degrees Celsius for 90 minutes developing time.**

- Ultraviolet light exposure: 5 minutes: not attempted.
- UV exposure 10 minutes No 61: A good development of colours showing purples, violets, mauves and blues that outnumbered the reds, pink-reds, orange-reds and pinks. Each disk showed at least five different developed colours.
- UV exposure for 20 minutes No 60: A good development of colours showing mauves, purples, violets and blues that competed with the reds, red-pinks, red-oranges. The colour orange appears in a few disks.
- UV exposure 30 minutes No 59: A good development of colours. Violet was the predominant colour seen in this triaxial. Purples mauves, 4 oranges and 1 blue competed with the reds, pink-reds, orange reds and pinks.
- **Conclusion:** Very good potential colour development in all three exposures.

**Figure 68**

**Group 1: Section B.**

Temperature/Heat development range: @ 490 degrees Celsius.

Time taken for colour development: 120 minutes.

Ultraviolet light exposure range: 30, 20, 10 minutes.



**Triaxial No: 58.**  
UV exposure: 10 minutes  
Heat development: @ 490 degrees Celsius  
for 120 minutes

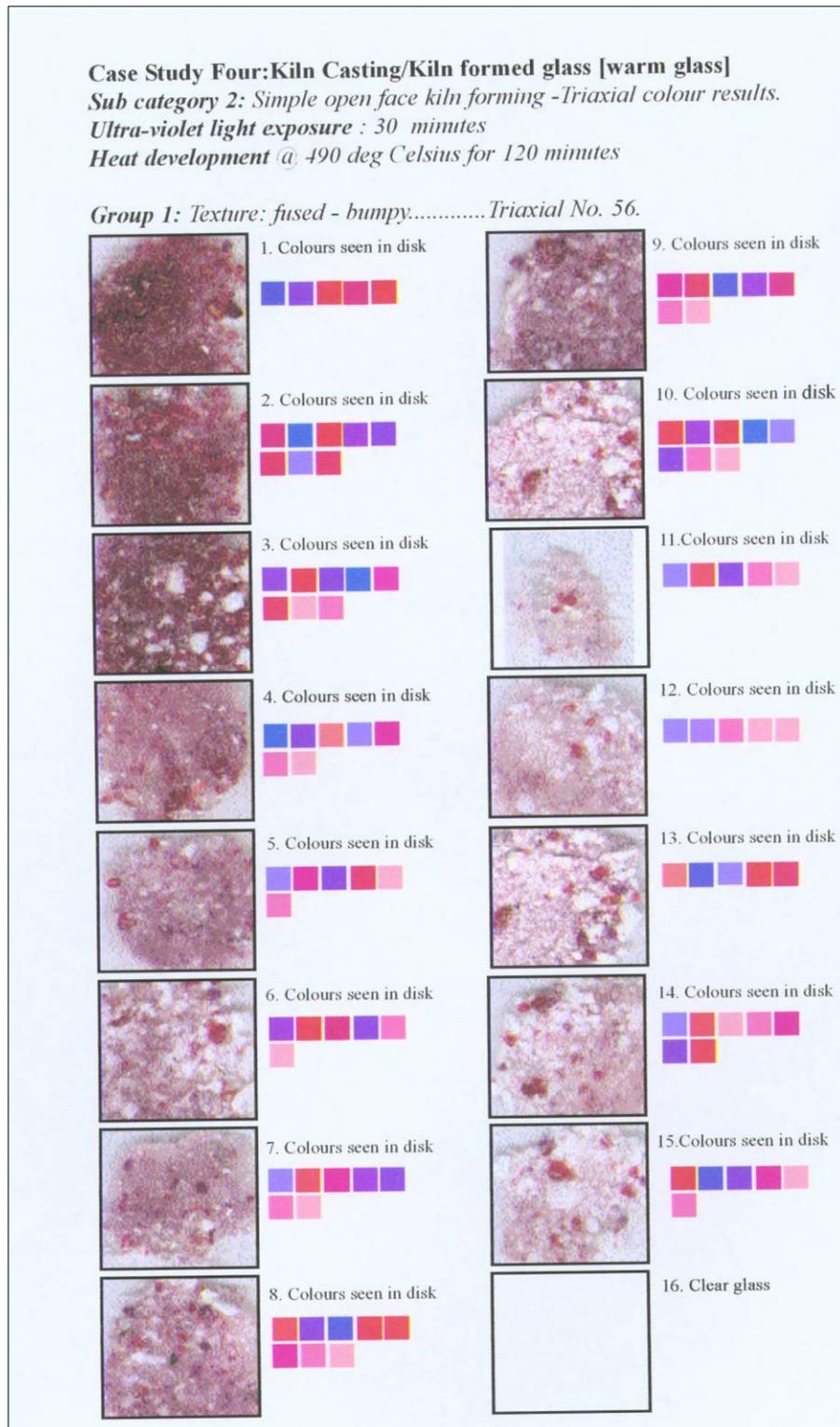


**Triaxial No: 57.**  
UV exposure: 20 minutes.  
Heat development: @ 490 degrees Celsius  
for 120 minutes.



**Triaxial No: 56.**  
UV exposure: 30 minutes.  
Heat development: @ 490 degrees Celsius  
For 120 minutes

**Figure 68a** (Triaxial No: 56)



**Figure 68b** (Triaxial No: 57)

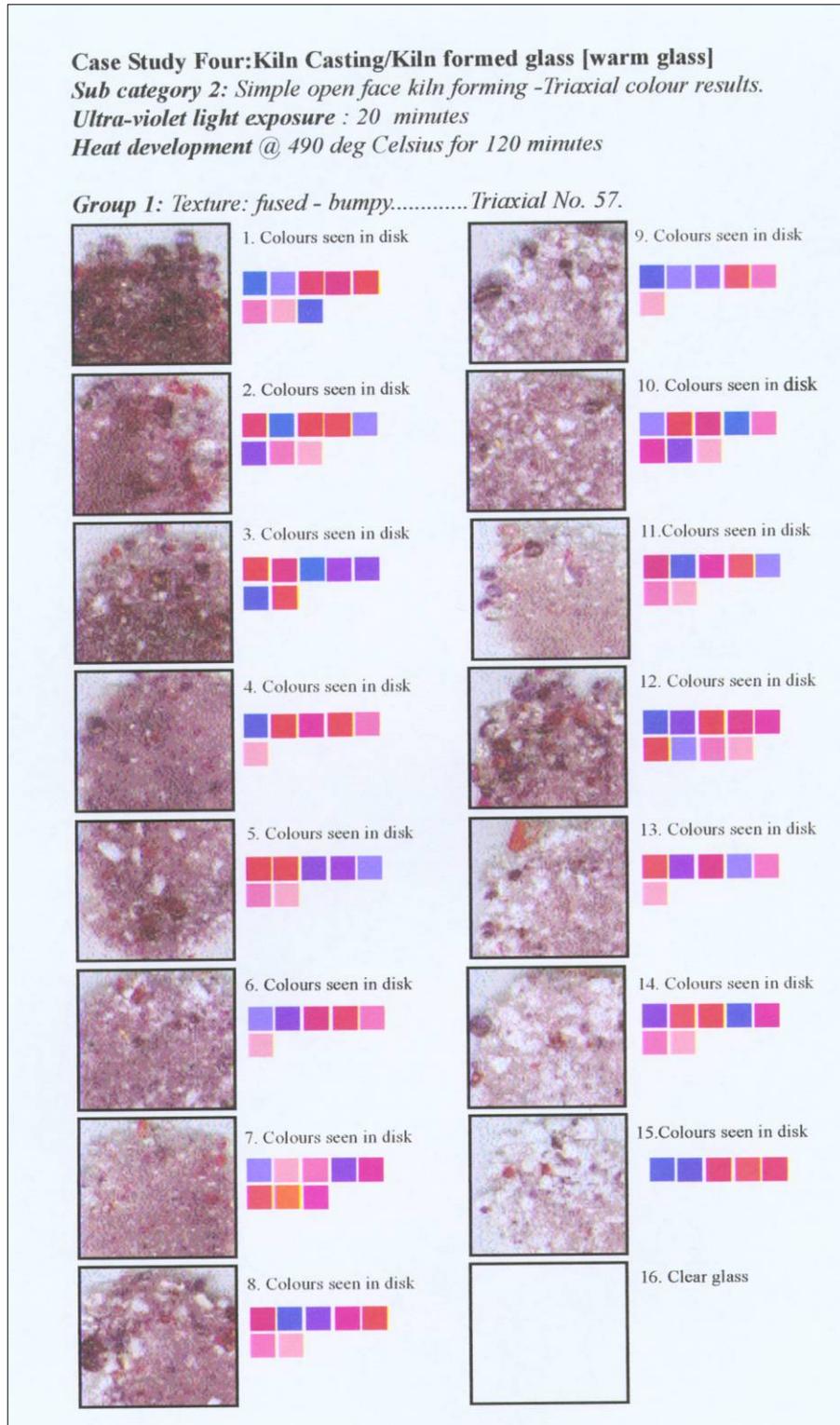
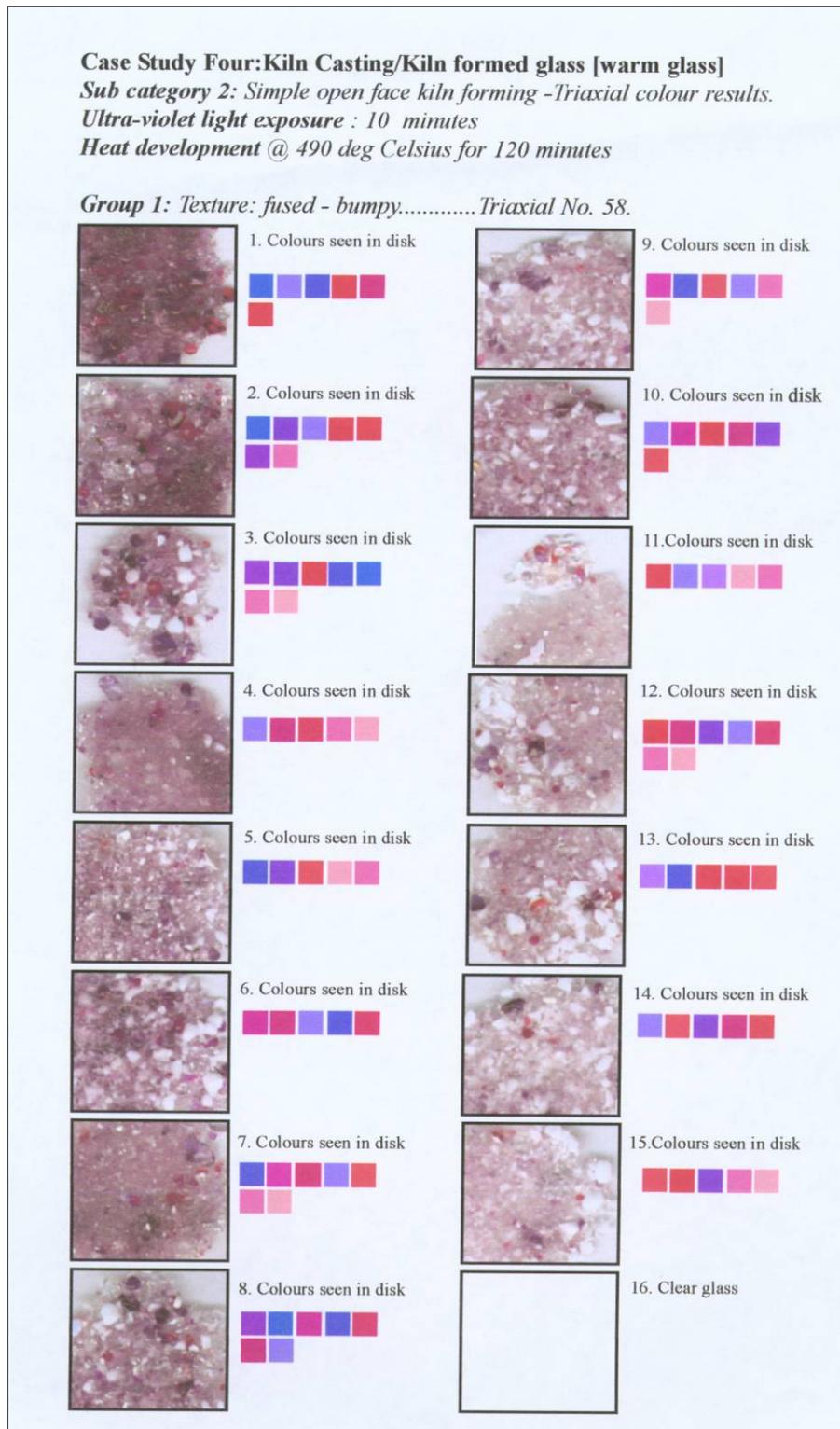
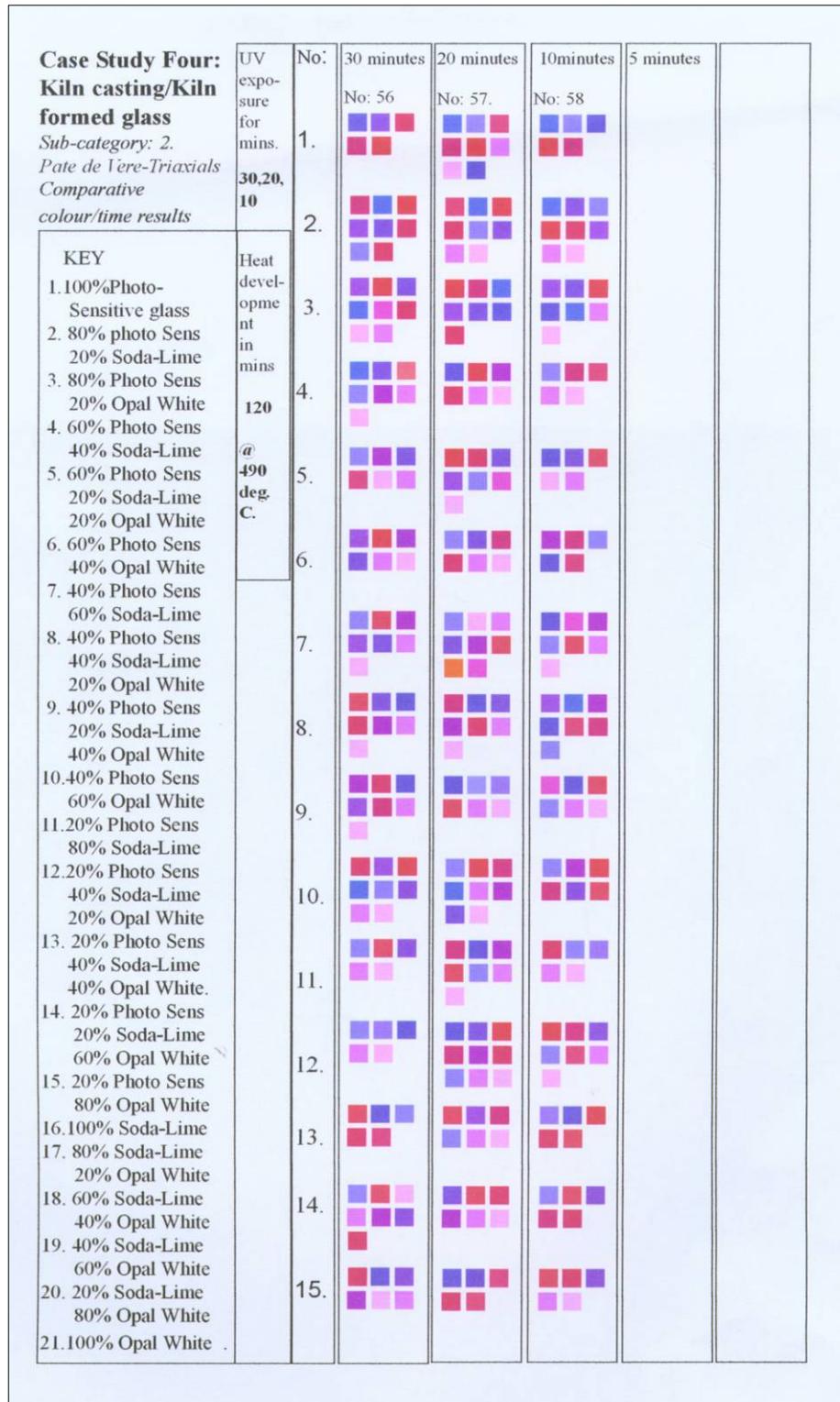


Figure 68c (Triaxial No: 58)





**Figure 68f** (Comparative colour/time results)



**Analysis of Figure 68** (Group 1.B).

**Section B:** 490 degrees Celsius for 120 minutes developing time.

- UV exposure of 5 minutes: Not attempted
- UV exposure 10 minutes No 58: The 17 violet and 9 mauve were main the colours present in this triaxial followed by 6 purple, 4 blue and 2 orange amongst the reds, pink-reds, orange-reds cerises and variety of pinks. There was good range of strong colour development.
- UV exposure 20minutes No 57: The 12 violet and 10 mauve were the main colours seen followed by 8 purple, 4 blue and four orange amongst the reds, pink-red, oranges reds, cerise and variety of pinks. There were many colours seen in this very good colour development.
- UV exposure 30minutes No 56: 17 violet, 9 mauve,6 purple 4 blue 5 orange and one salmon pink were seen in this very good colour development in amongst the reds, pink-red, orange-reds and pinks.
- **Conclusion:** Excellent to very good potential colour development in all three exposures.

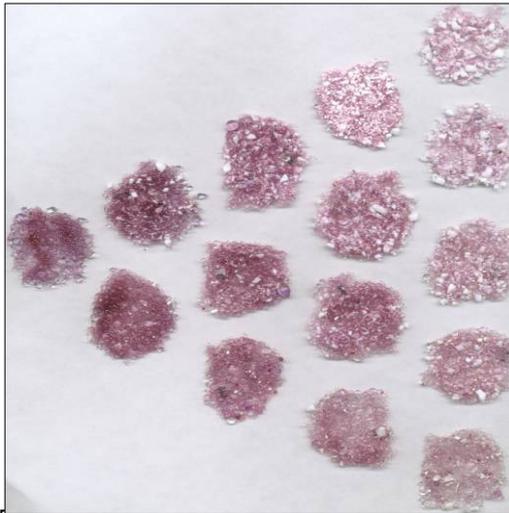
**Figure 69**

**Group 1: Section C.**

Temperature/Heat development range: @ 490 degrees Celsius.

Time taken for colour development 240 minutes.

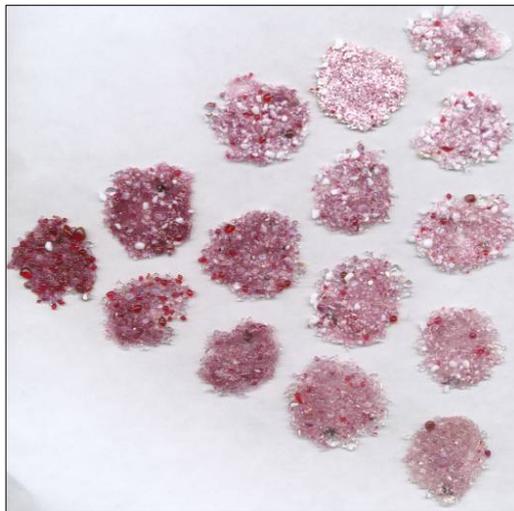
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



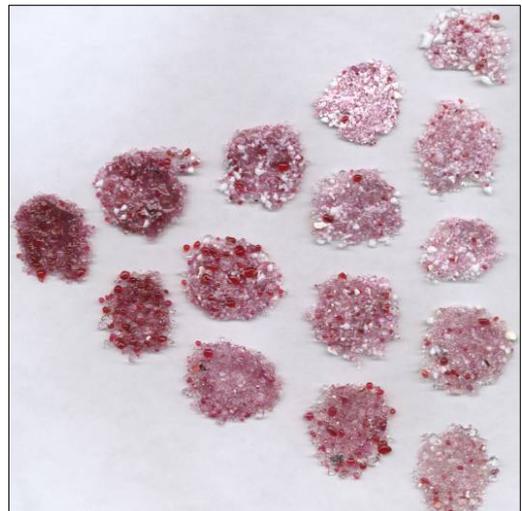
**Triaxial No: 55.**  
UV exposure: 5 minutes  
Heat development: @ 490 degrees Celsius  
for 240 minutes.



**Triaxial No: 54.**  
UV exposure: 10 minutes  
Heat development: @ 490 degrees Celsius  
for 240 minutes.

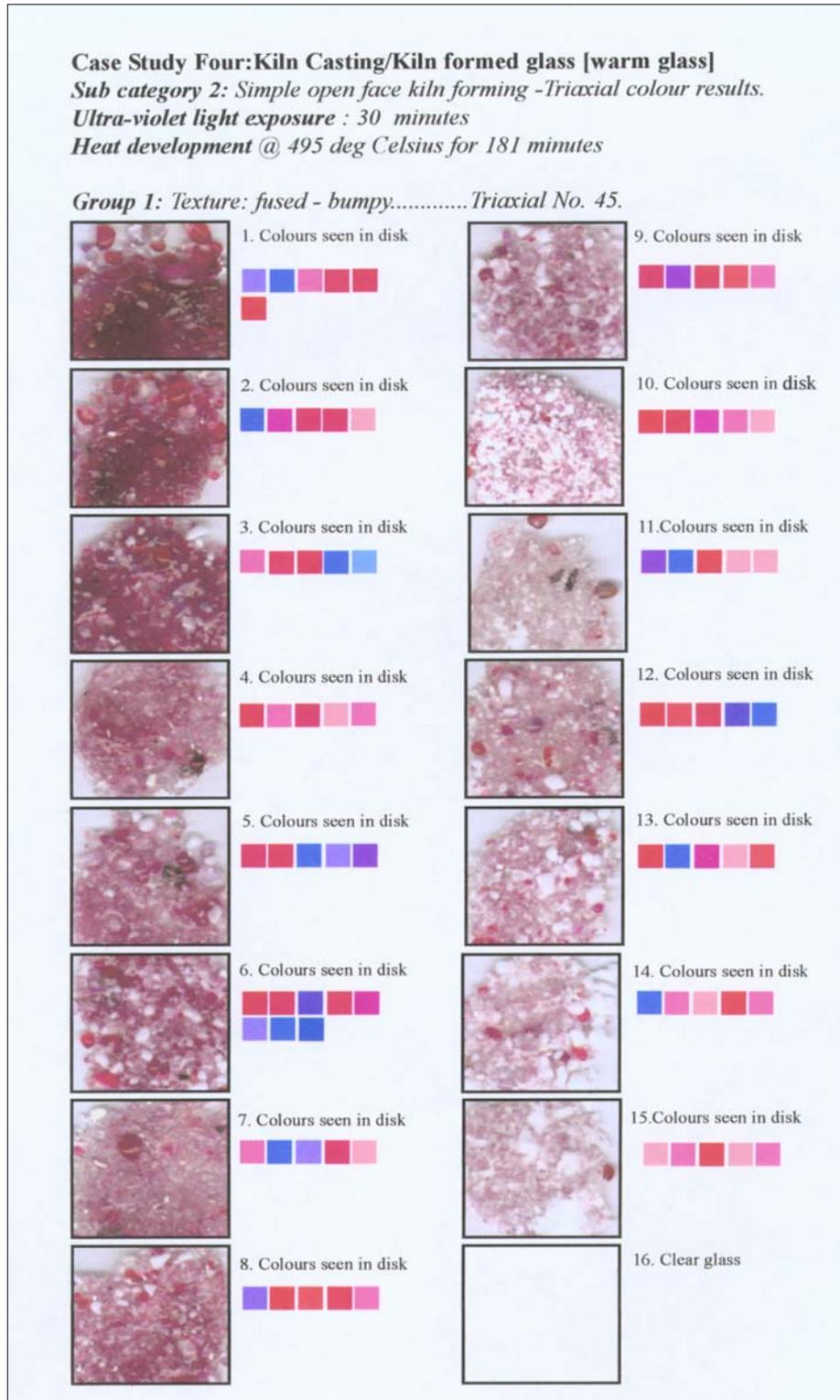


**Triaxial No: 53.**  
UV exposure: 20 minutes.  
Heat development: @ 490 degrees Celsius  
for 240 minutes.



**Triaxial No: 52.**  
UV exposure: 30 minutes.  
Heat development: @ 490 degrees Celsius  
For 240 minutes.

**Figure 69a** (Triaxial No: 52)



**Figure 69b** (Triaxial No: 53)

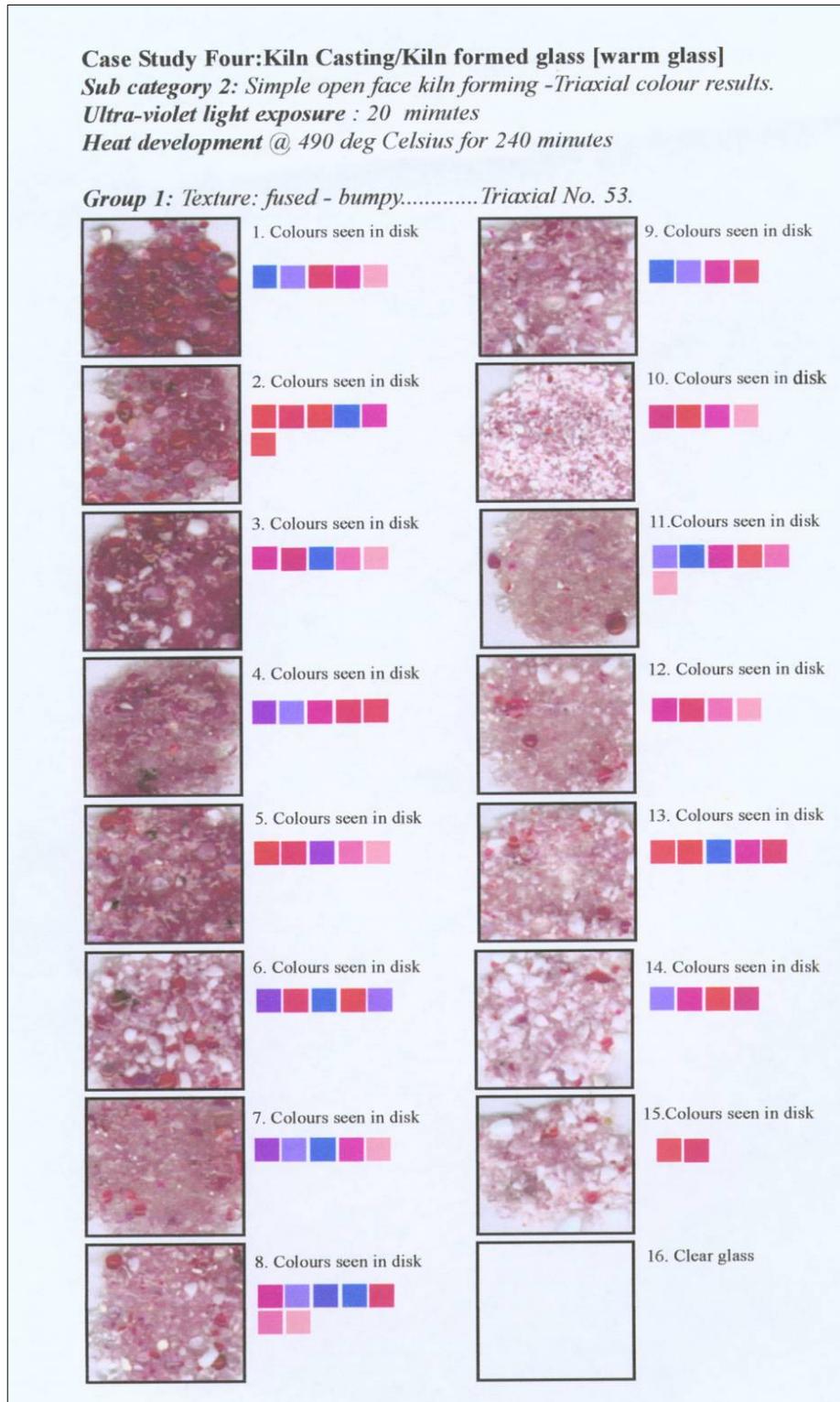
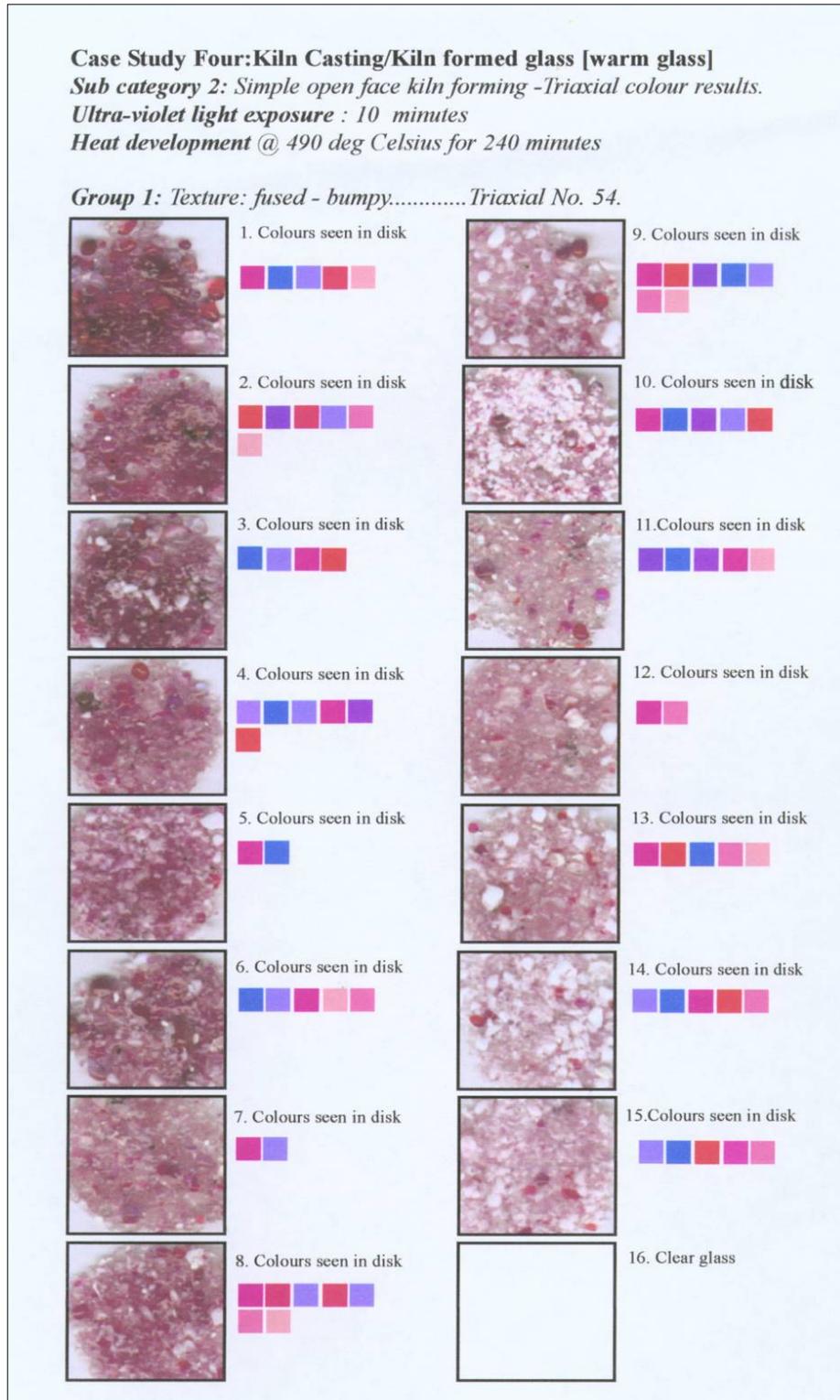
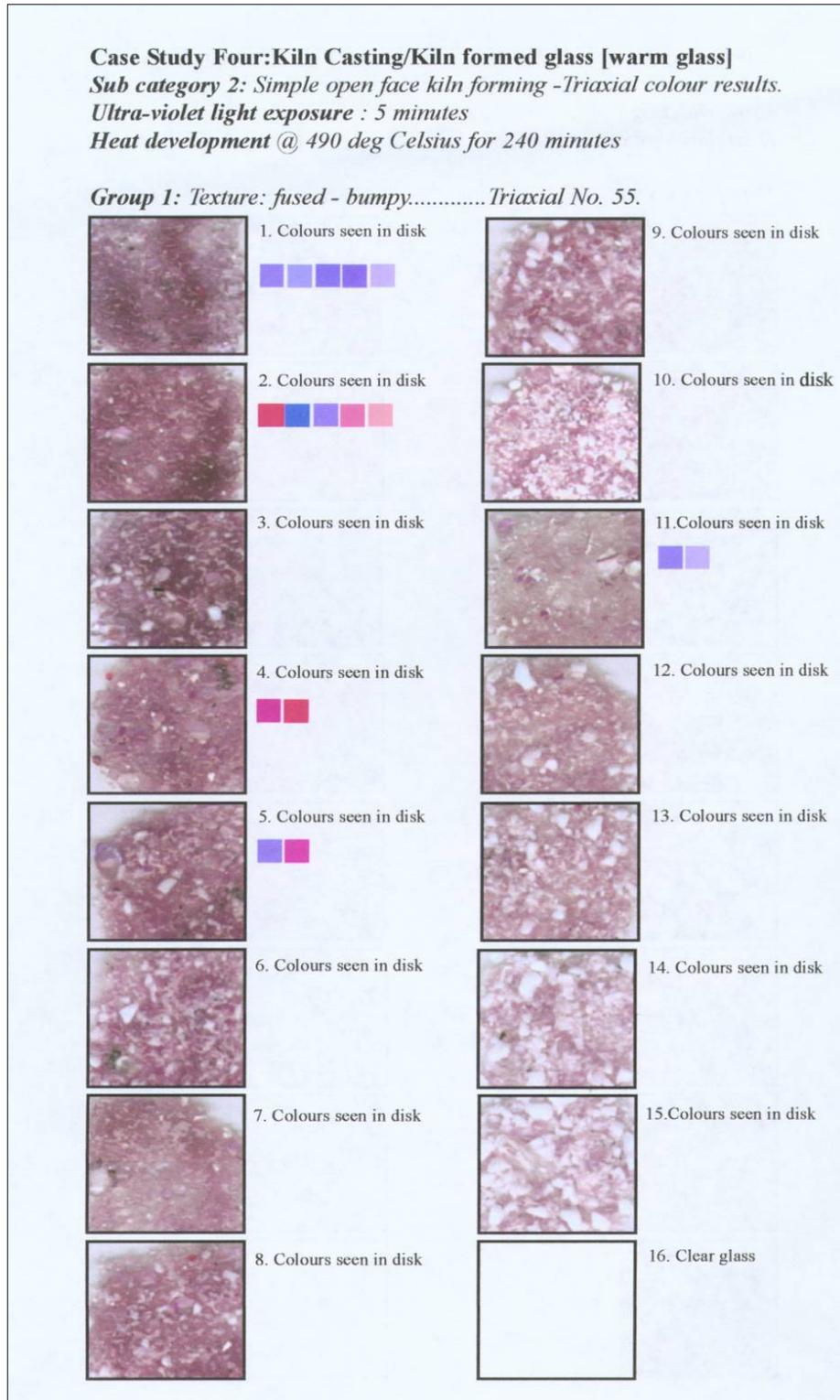


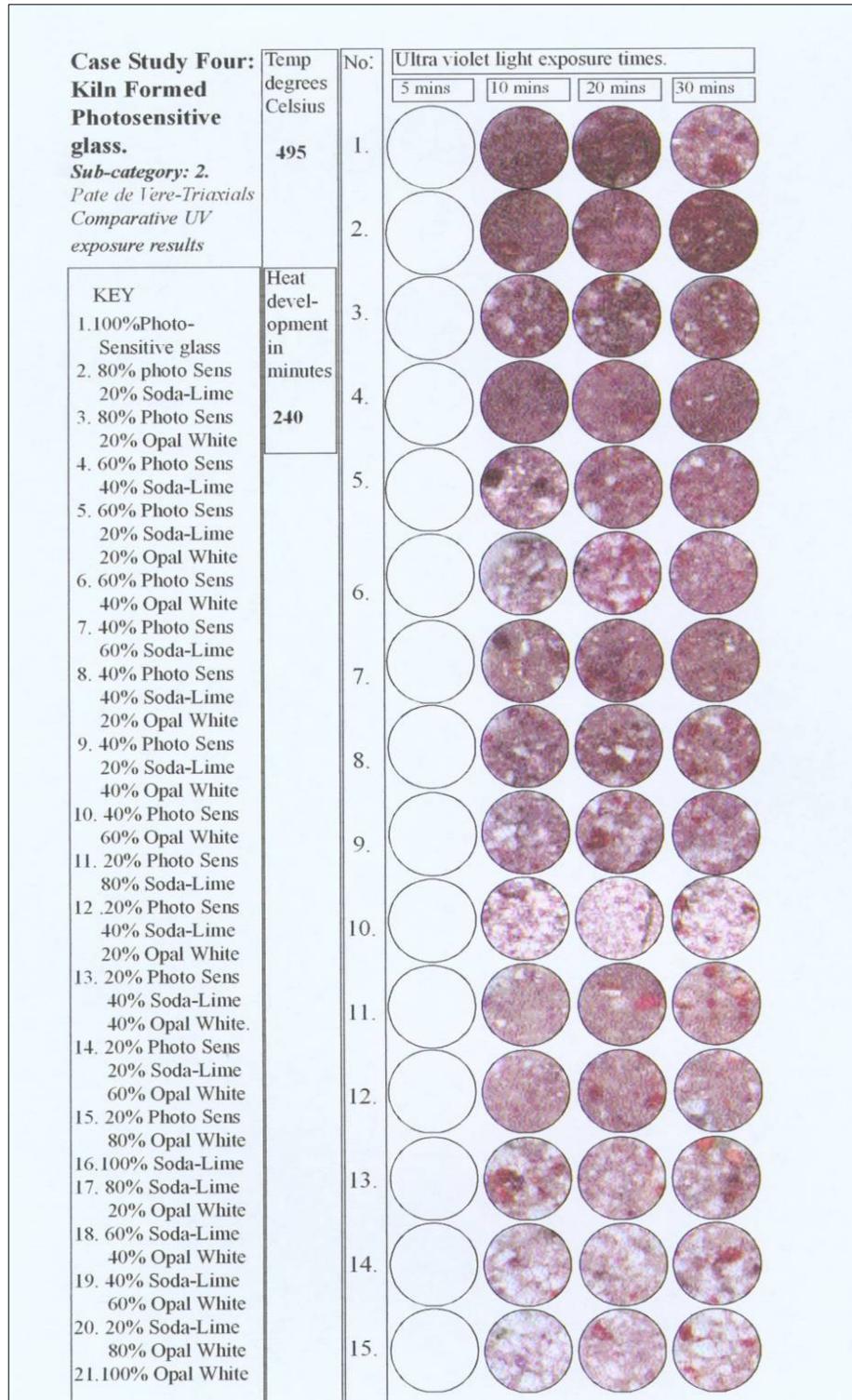
Figure 69c (Triaxial No: 54)



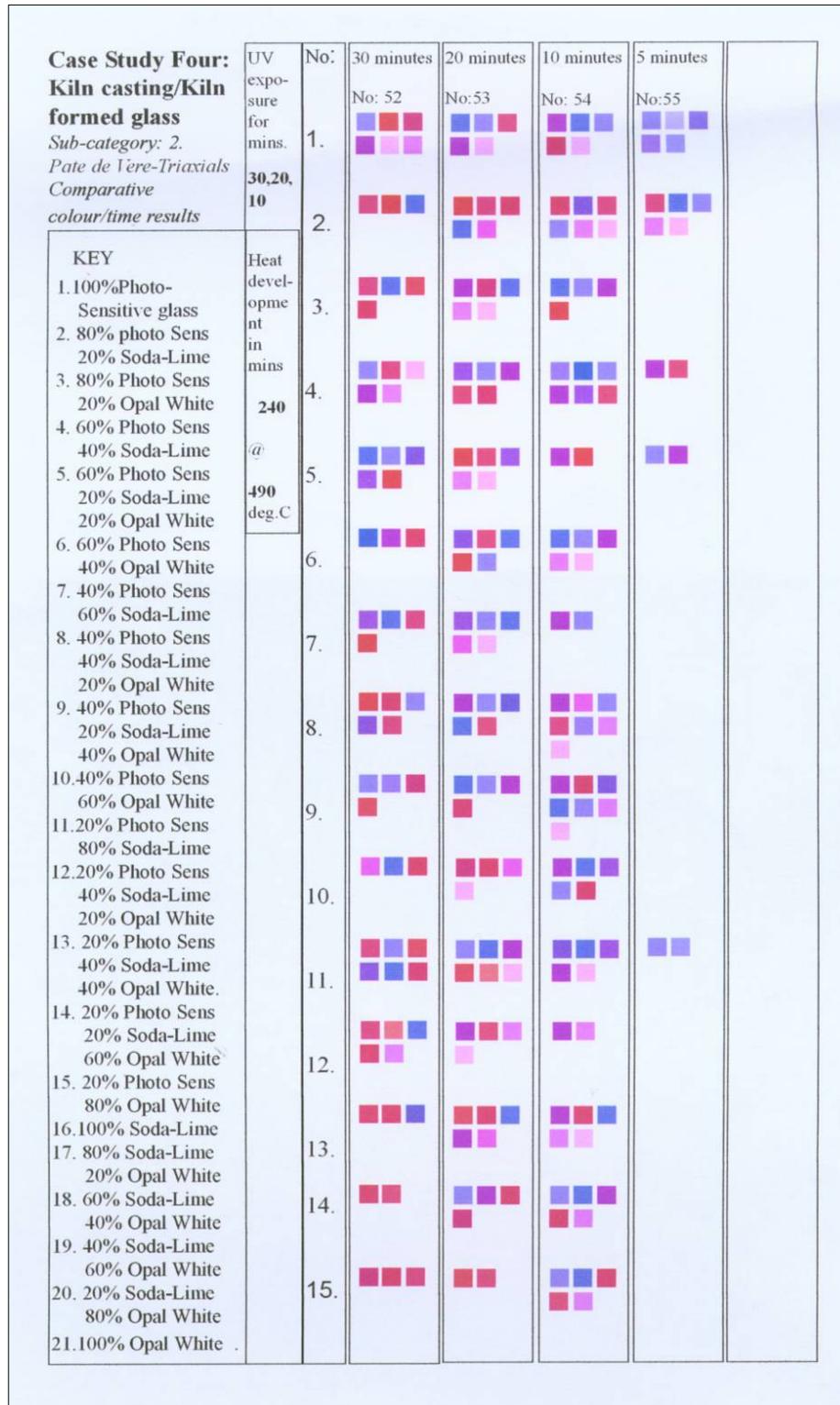
**Figure 69e** (Triaxial No:55)



**Figure 69d** (Comparative timed UV exposure results)



**Figure 69f** (Comparative colour/time results)



## Analysis Figure 69

Section C: for 490 degrees Celsius for 240 minutes developing time.

- UV exposure:
- 5 minutes No 55: A limited strike of colour development of 9 mauves, 1 blue and some pinks seen in disks 1,2,4,5 and 11.
- 10 minutes No 54: A moderate colour development of 11 blues, 11 mauves and 6 violets were the dominant colours seen with the reds, red-pinks, orange-reds plus variety of pinks.
- 20 minutes No 53: A moderate to good development of strong colours. 11 cerise and dark pinks, 9 blues, 8 mauves, 4 violet and 3 orange were the main colours seen amongst the red, pink-reds, orange-reds and variety of pinks.
- 30 minutes No 52: A moderate development of colours. 8 blues, 7 mauves, 5 violet, 2 orange and 1 salmon were the main colours seen amongst the red, pink-reds, orange-reds cerise and variety of pinks.
- **Conclusion:** A moderate colour development potential for a wide colour range at 10, 20 and 30 minutes, when required for a stronger glass body.

**Figure 70**

**Group 1: Section D.**

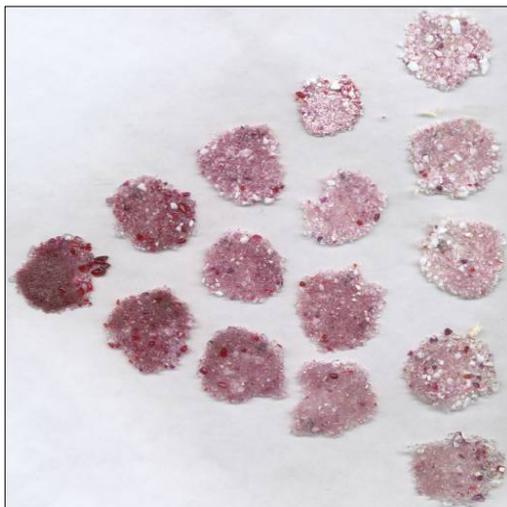
Temperature/Heat development range: @ 495 degrees Celsius.

Time taken for colour development 120 minutes.

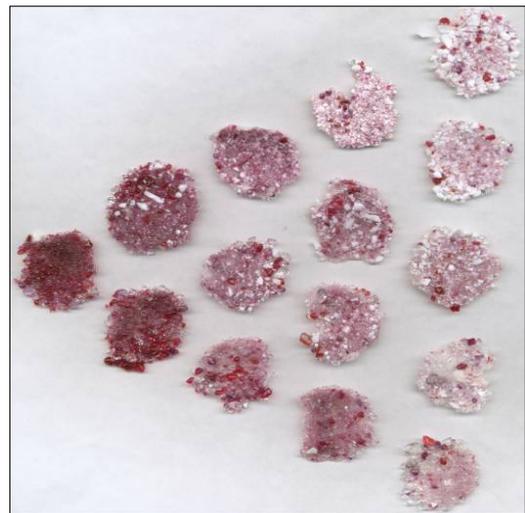
Ultraviolet light exposure range: 30, 20, 10 minutes.



**Triaxial No: 51.**  
UV exposure: 10 minutes  
Heat development: @ 495 degrees Celsius  
for 120 minutes.

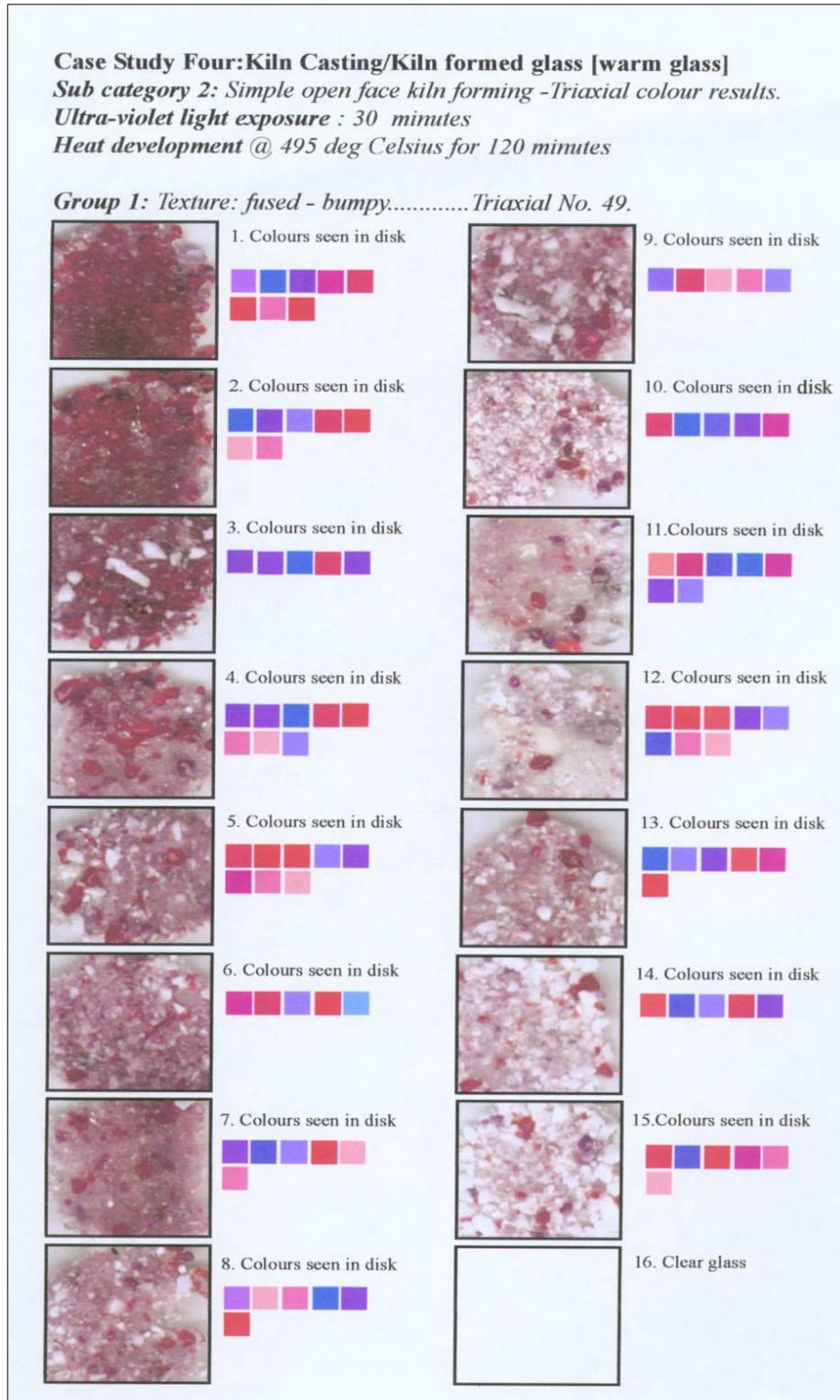


**Triaxial No: 50.**  
UV exposure: 20 minutes  
Heat development: @ 495 degrees Celsius  
for 120 minutes.



**Triaxial No: 49.**  
UV exposure: 30 minutes.  
Heat development: @ 495 degrees Celsius  
For 120 minutes.

**Figure 70a** (Triaxial No: 49)



**Figure 70b** (Triaxial No: 50)

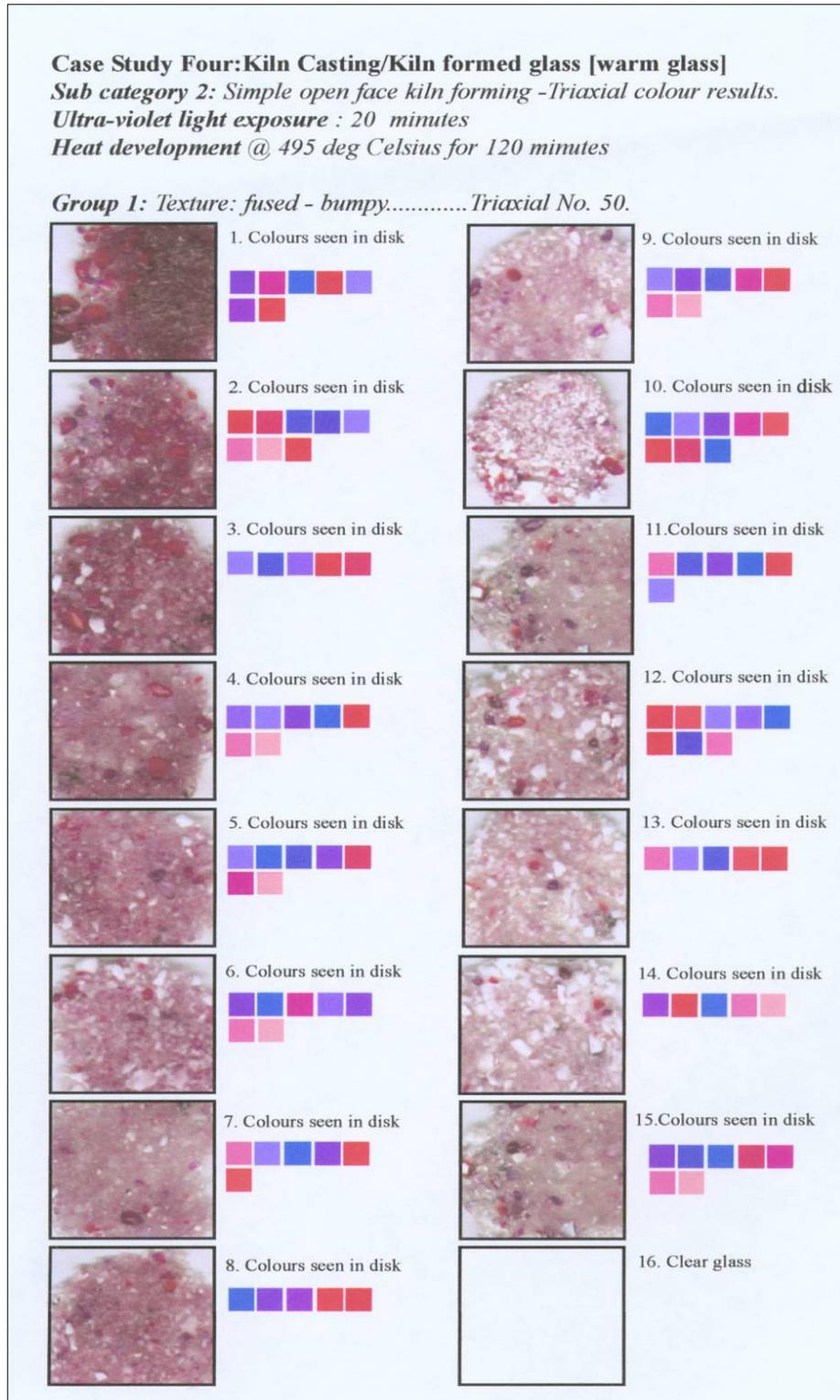
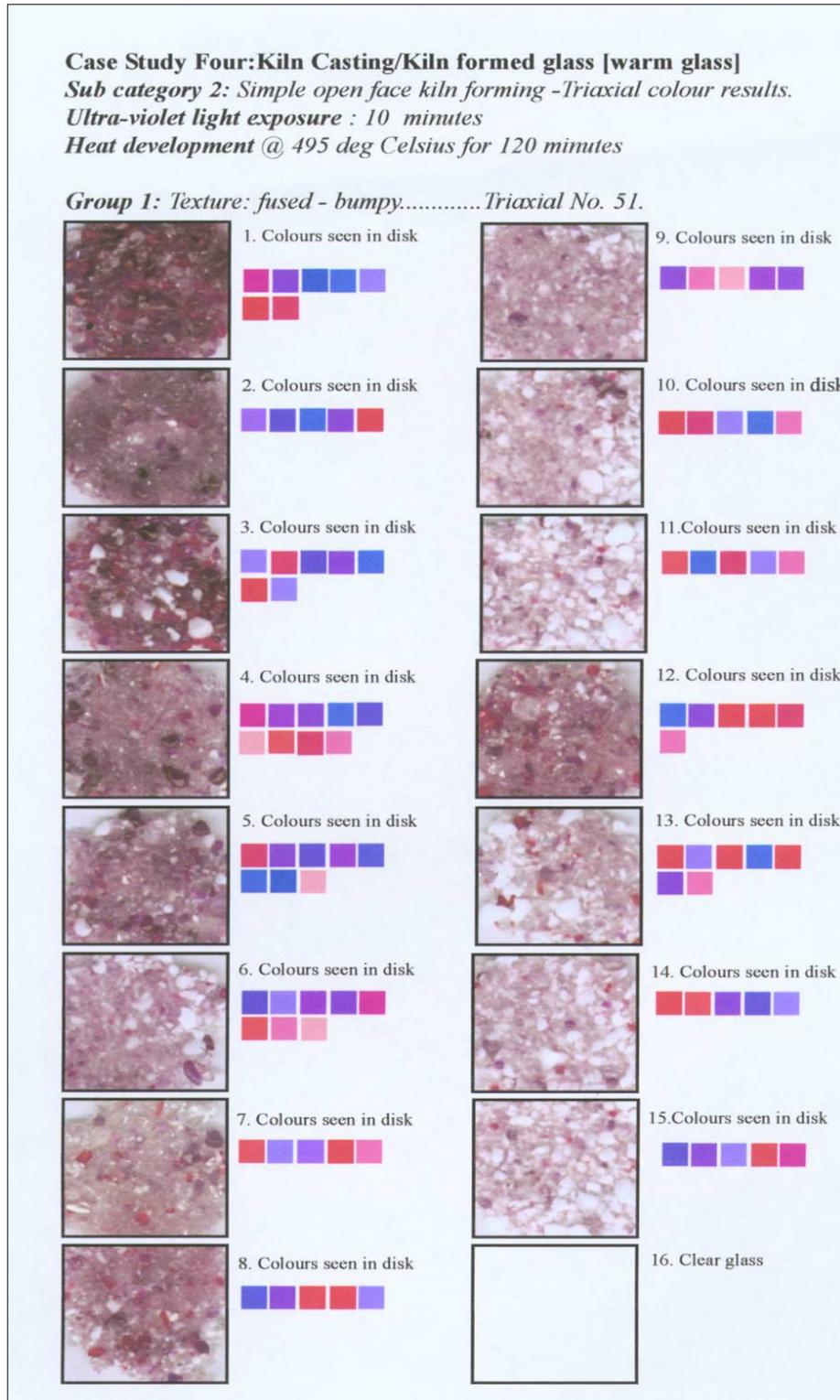


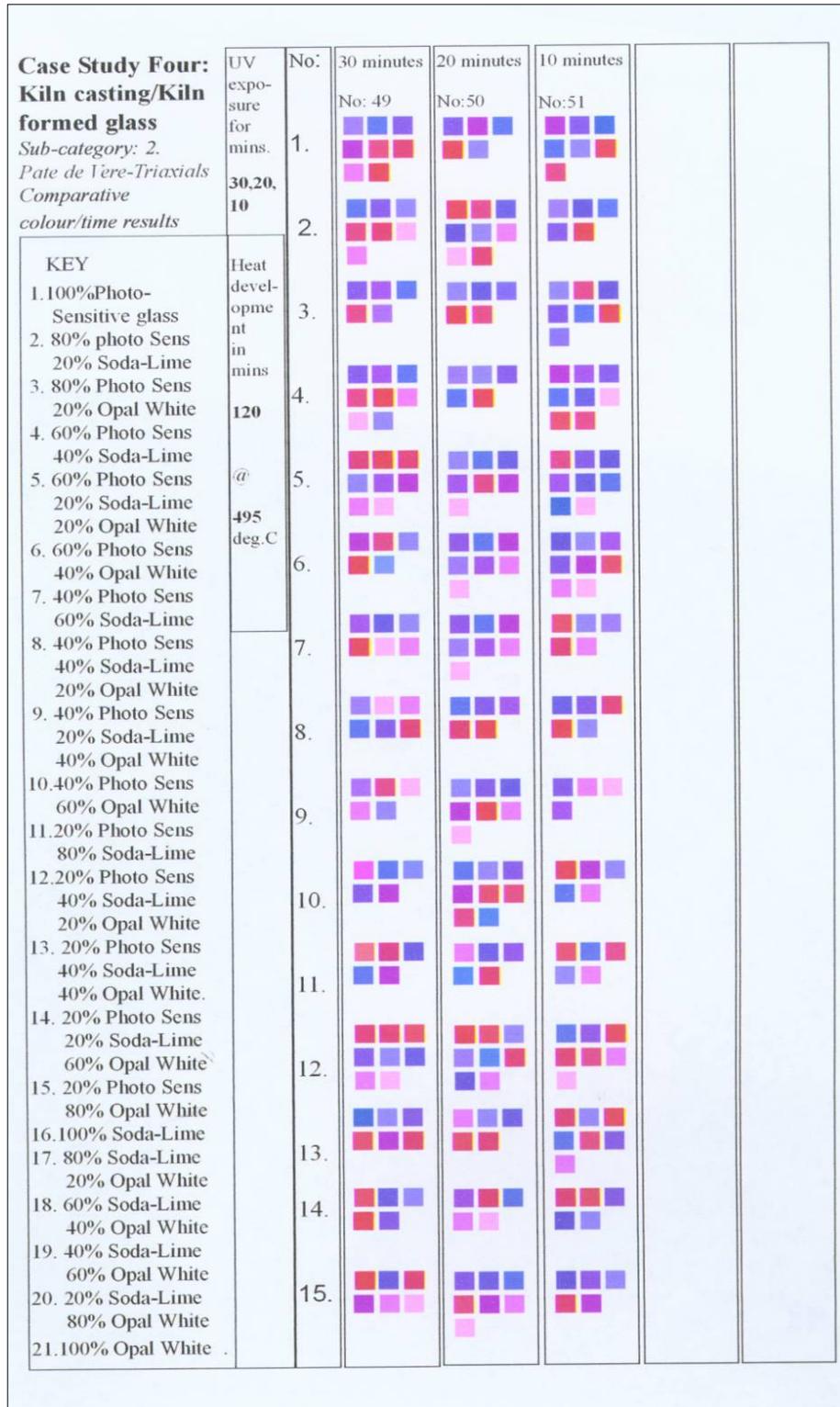
Figure 70c (Triaxial 51)



**Figure 70d** (Comparative timed UV exposure results)

Case Study Four: Kiln Formed Photosensitive glass		Temp degrees Celsius	No:	Ultra violet light exposure times.			
				5 mins	10 mins	20 mins	30 mins
<i>Sub-category 1:</i> <i>Pate de Vere</i> <i>Triaxials</i> <i>Comparative UV</i> <i>Exposure Results</i>		495	1.				
			2.				
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		Heat development in minutes	3.				
			4.				
			5.				
			6.				
			7.				
			8.				
			9.				
			10.				
			11.				
			12.				
			13.				
			14.				
			15.				

**Figure 70f** (Comparative colour/time results)



### **Analysis Figure 70**

Section D: for 495 degrees Celsius for 120 minutes developing time.

- UV exposure:
- 5 minutes: Not attempted.
- 10 minutes No 51: A very good colour development showing a range of strong colours. 11 blue, 17 violet, 9 purple, 9 mauves and 5 orange amongst the reds, pink-reds, orange-reds, and variety of pinks.
- 20 minutes No 50: A very good colour development of a range of colours. 13 blue, 13 violet, 13 mauve, 8 purple and 4 orange were seen amongst the reds, pink-reds, orange-reds and variety of pinks.
- 30 minutes No 49: A very good colour development range. 16 violet, 8 blue, 8 mauve, 5 purple and 3 orange were the main colours seen amongst the reds, pink-reds, orange-reds and variety of pinks.
- **Conclusion:** Shows a very good potential for colour development.

**Figure 71**

**Group 1: Section E.**

Temperature/Heat development range: @ 495 degrees Celsius.

Time taken for colour development: 180 minutes.

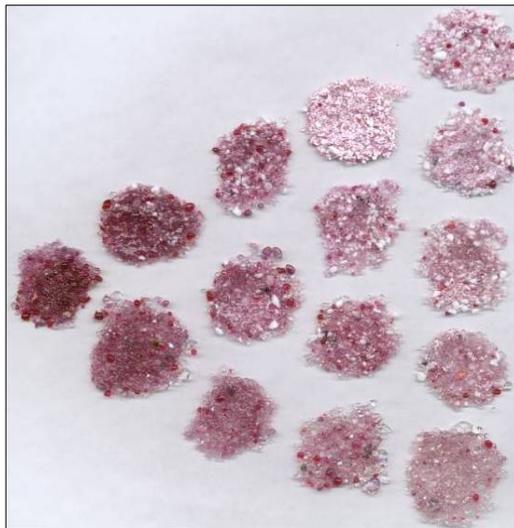
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 48.**  
UV exposure: 5 minutes  
Heat development: @ 495 degrees Celsius  
for 180 minutes.



**Triaxial No: 47**  
UV exposure: 10 minutes  
Heat development: @ 495 degrees Celsius  
for 180 minutes.

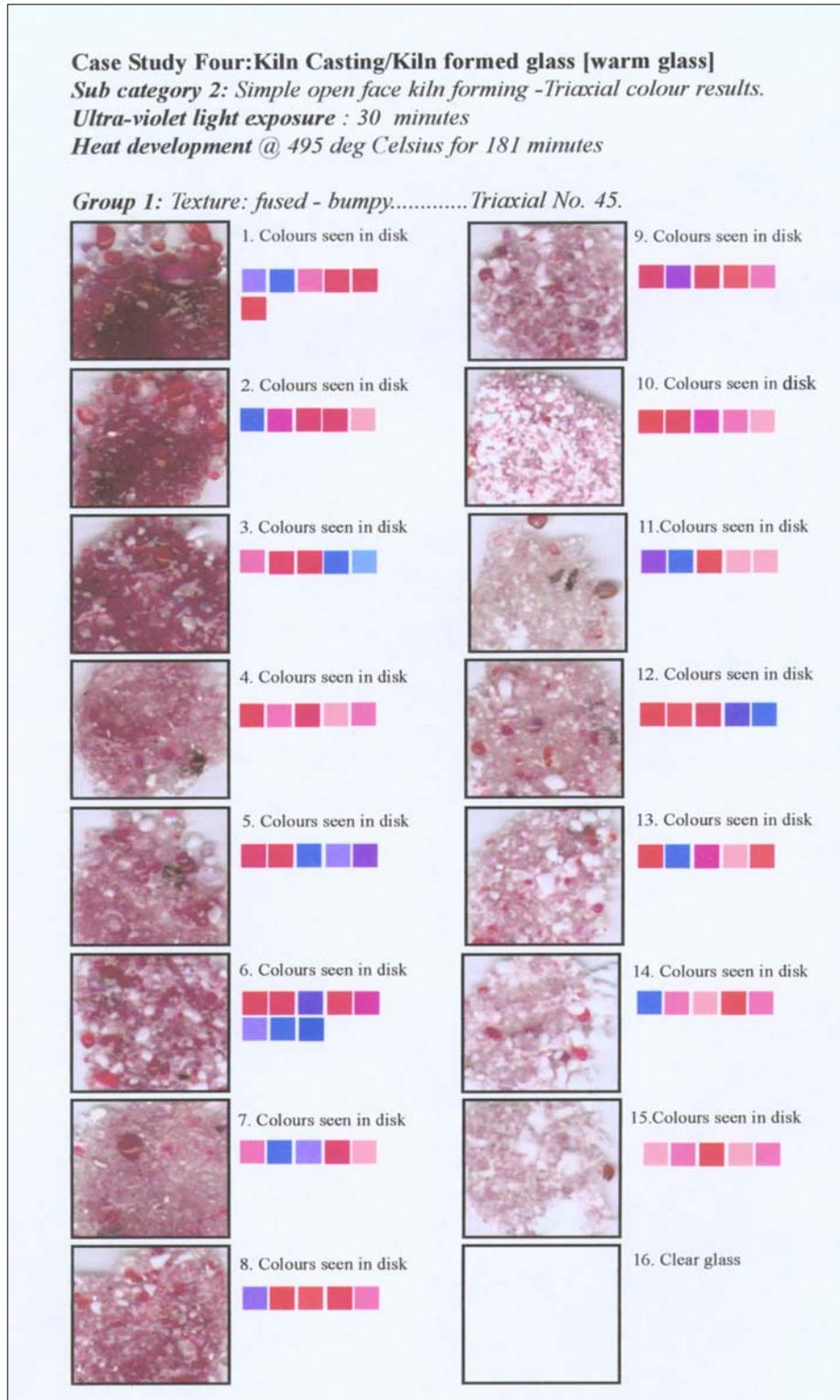


**Triaxial No: 46**  
UV exposure: 20 minutes  
Heat development: @ 495 degrees Celsius  
for 180 minutes.

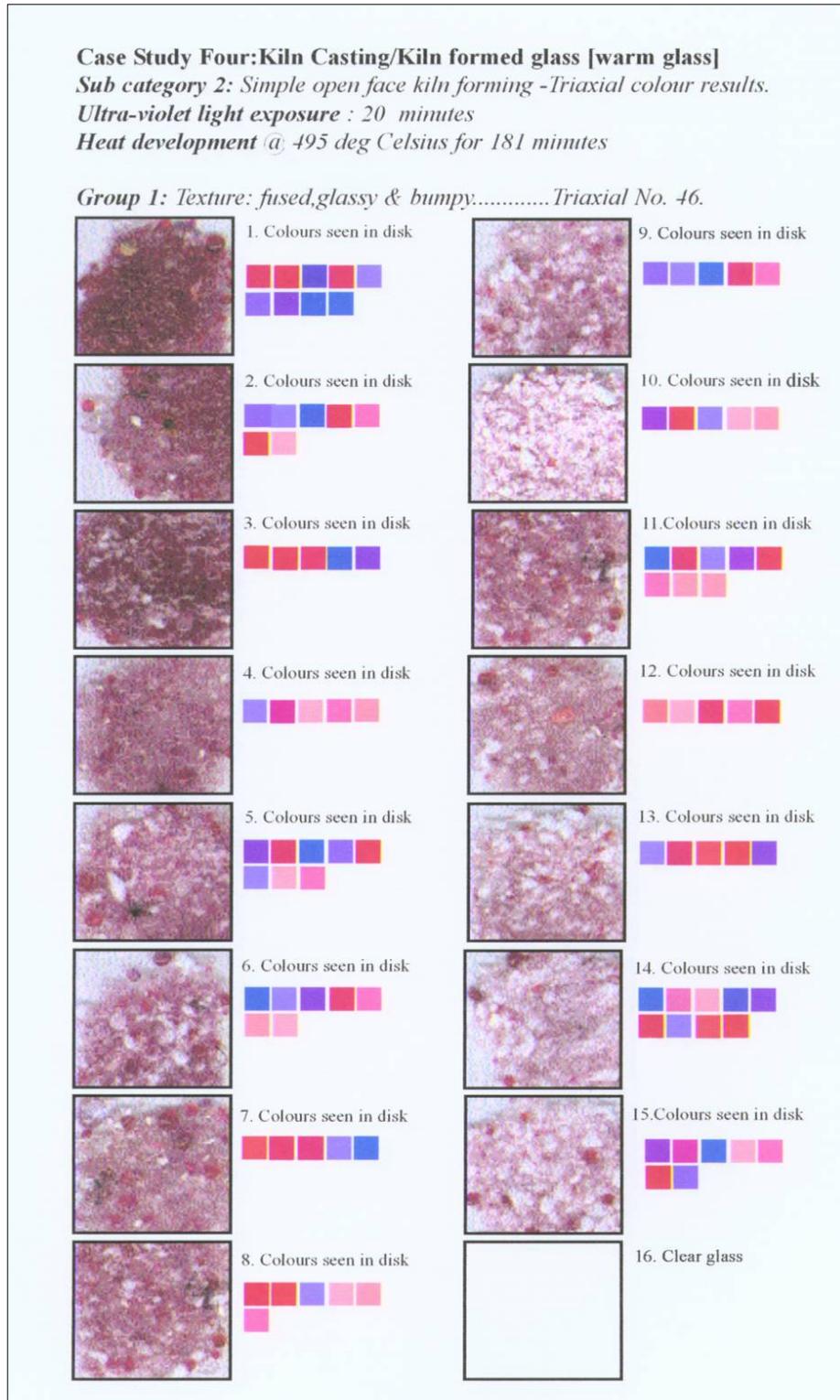


**Triaxial No: 45**  
UV exposure: 30 minutes  
Heat development: @ 495 degrees Celsius  
for 180 minutes.

**Figure 71a** (Triaxial No: 45)



**Figure 71b** (Triaxial No: 46)



**Figure 71c** (Triaxial No: 47)

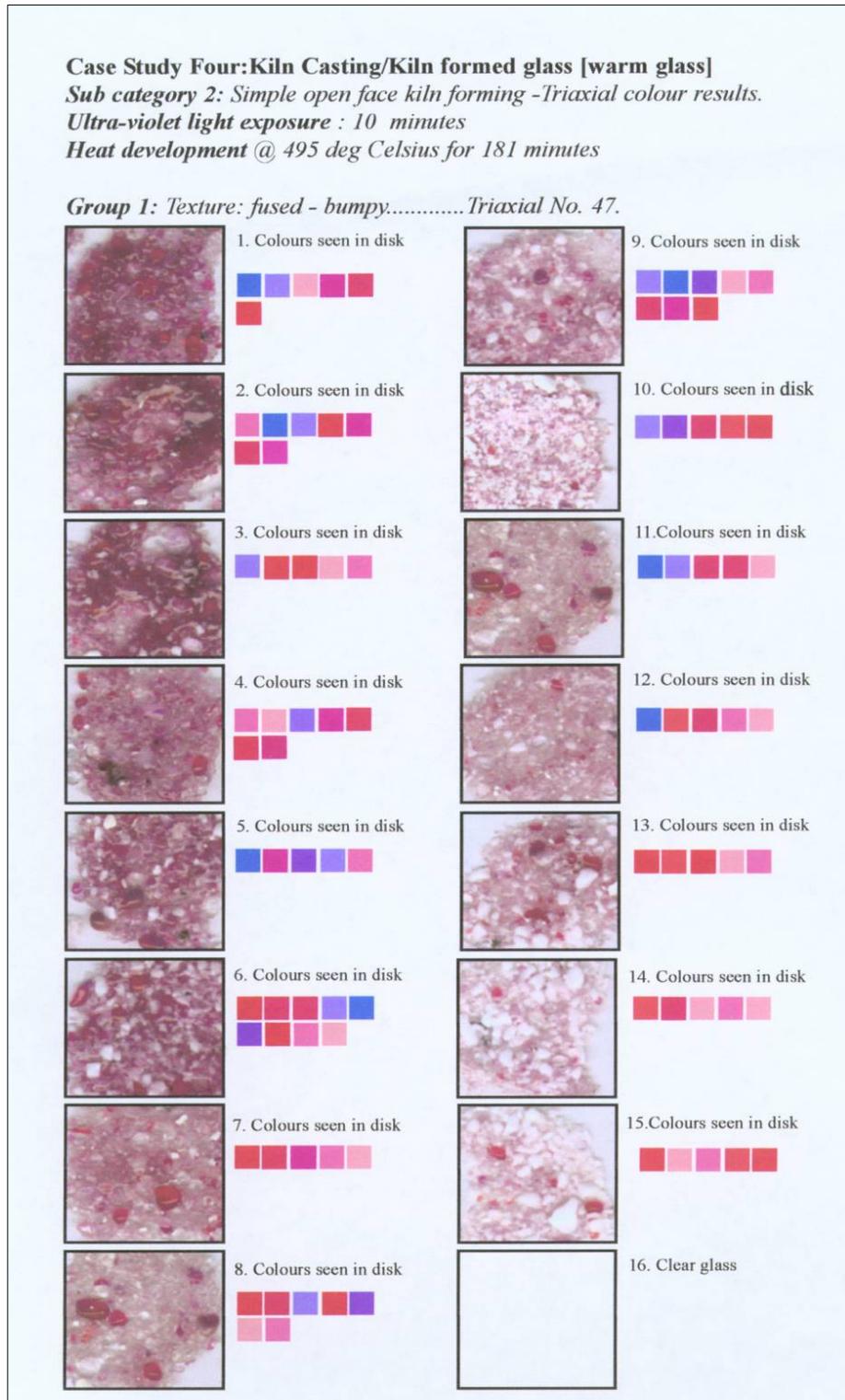
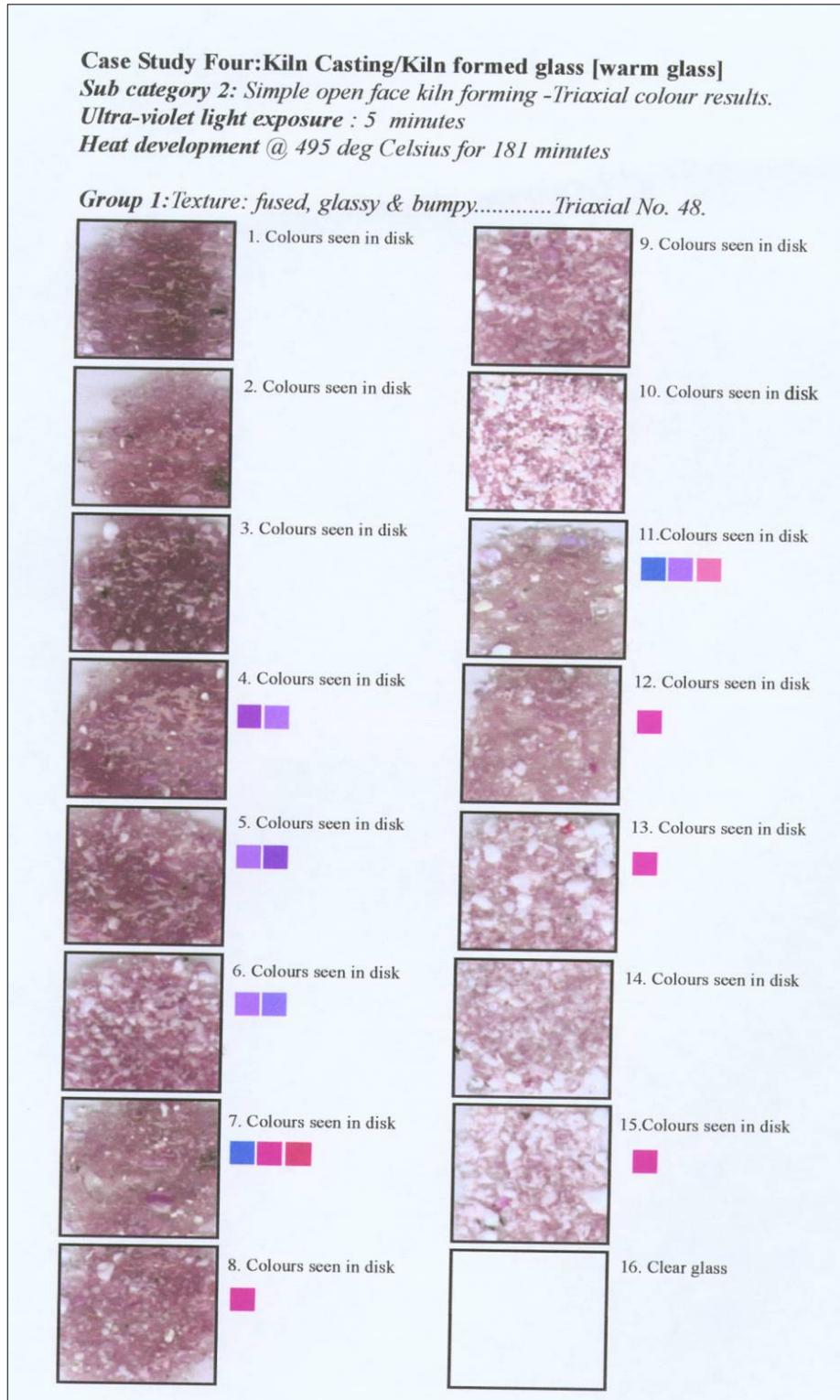


Figure 71e (Triaxial No: 48)



**Figure 71d** (Comparative timed UV exposure results)

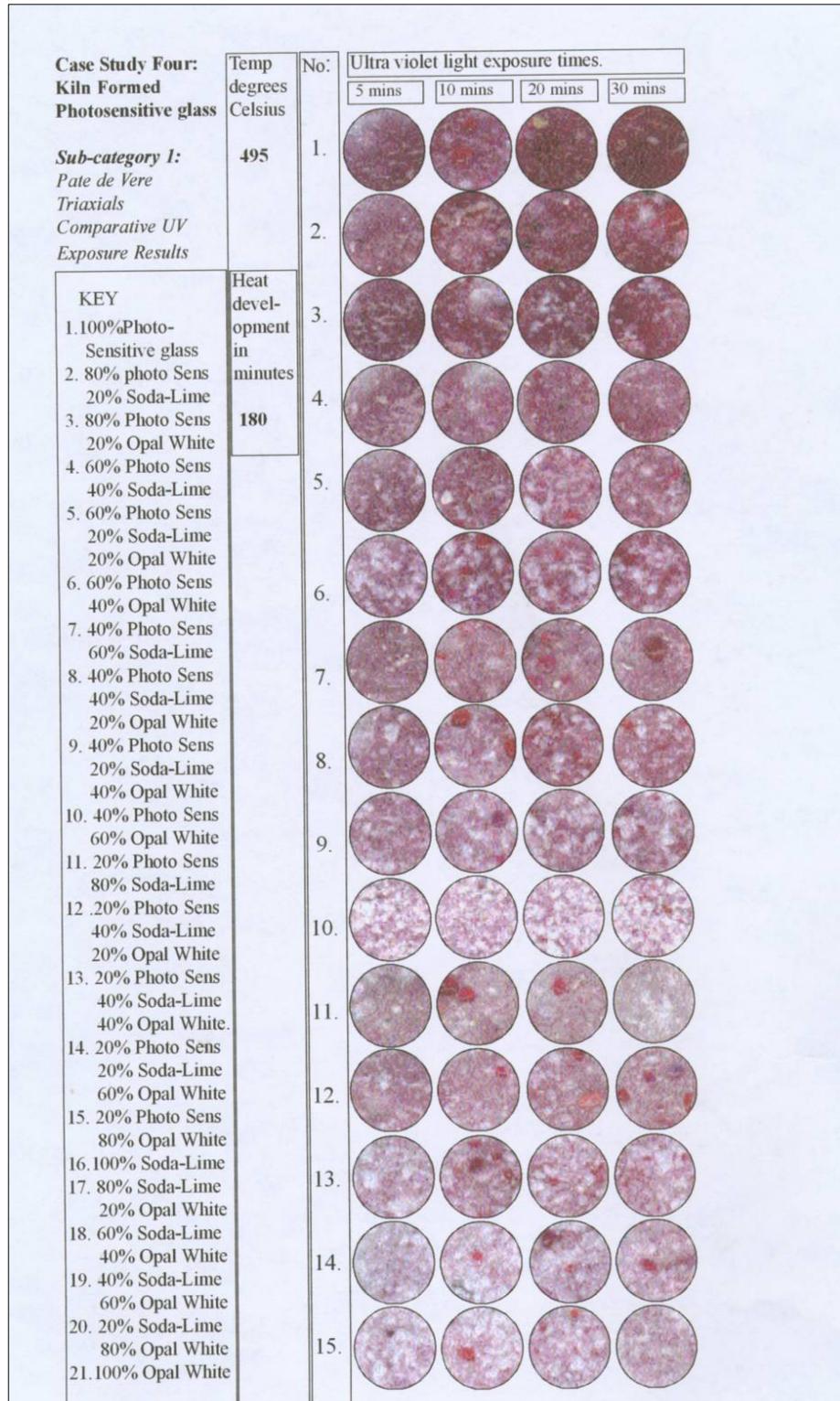
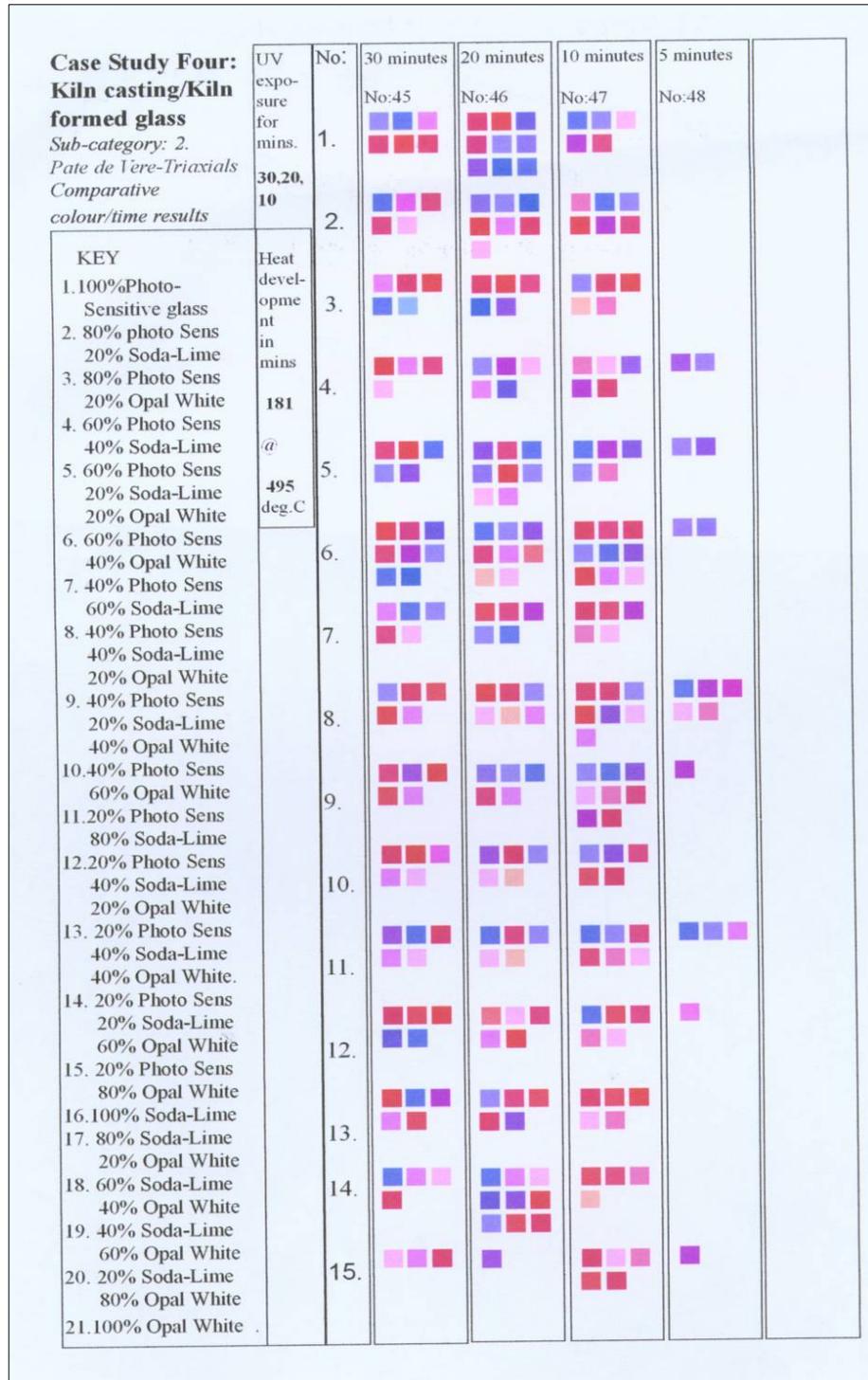


Figure 71f (Comparative colour/time results)



## Analysis Figure 71

Section F: for 495 degrees Celsius 180 minutes.

- UV exposure:
- 5 minutes No.48: A limited development of strong colours. 2 blue, 4 mauves, 2 violet and 4 cerise were seen amongst a few pinks and dark pinks. Disks 4,5,6,8,9,11,12,15 showing early strong colour development
- 10 minutes No. 47:A good colour development of 7 blue, 9 mauve, 6 violet and 4 orange amongst the reds, red-pinks, orange-reds, cerise and variety of pinks.
- 20 minutes No. 46: A very good colour development showing 15 mauve, 11 blue, 8 violet, 2 purple, 1 salmon-pink and 2 orange were seen amongst the reds, pink-reds, orange-reds, cerise and variety of pinks.
- 30 minutes No. 45: A good colour development. 11 blue, 5 mauve, 3 violet, 2 purple and 5 orange were seen amongst the reds, pink-reds, orange-reds and variety of pinks.
- **Conclusion:** These results show a good potential for colour development at the longer time for heat development at the lower temperature of 495 degrees Celsius.

**Figure 72**

**Group 1: Section F**

Temperature/Heat development range: @ 495 degrees Celsius.

Time taken for colour development 240 minutes

Ultraviolet light exposure range: 30, 20, 10 minutes.



**Triaxial No: 44.**  
UV exposure: 10 minutes.  
Heat development: @ 495 degrees Celsius  
for 240 minutes.

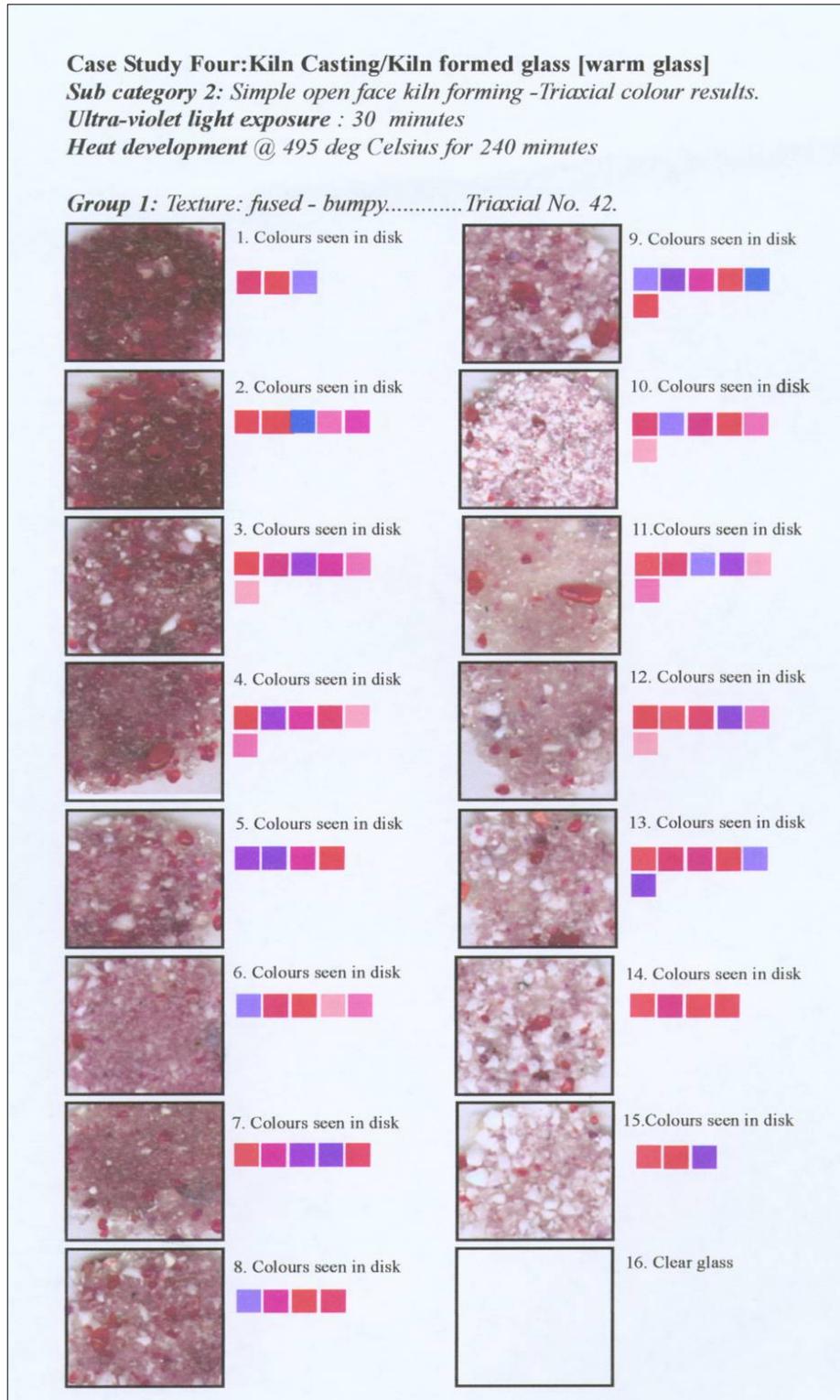


**Triaxial No: 43**  
UV exposure: 20 minutes.  
Heat development: @ 495 degrees Celsius  
for 240 minutes.



**Triaxial No: 42**  
UV exposure: 30 minutes  
Heat development: @ 495 degrees Celsius  
for 240 minutes.

**Figure 72a** (Triaxial No: 42)



**Figure 72b** (Triaxial No: 43)

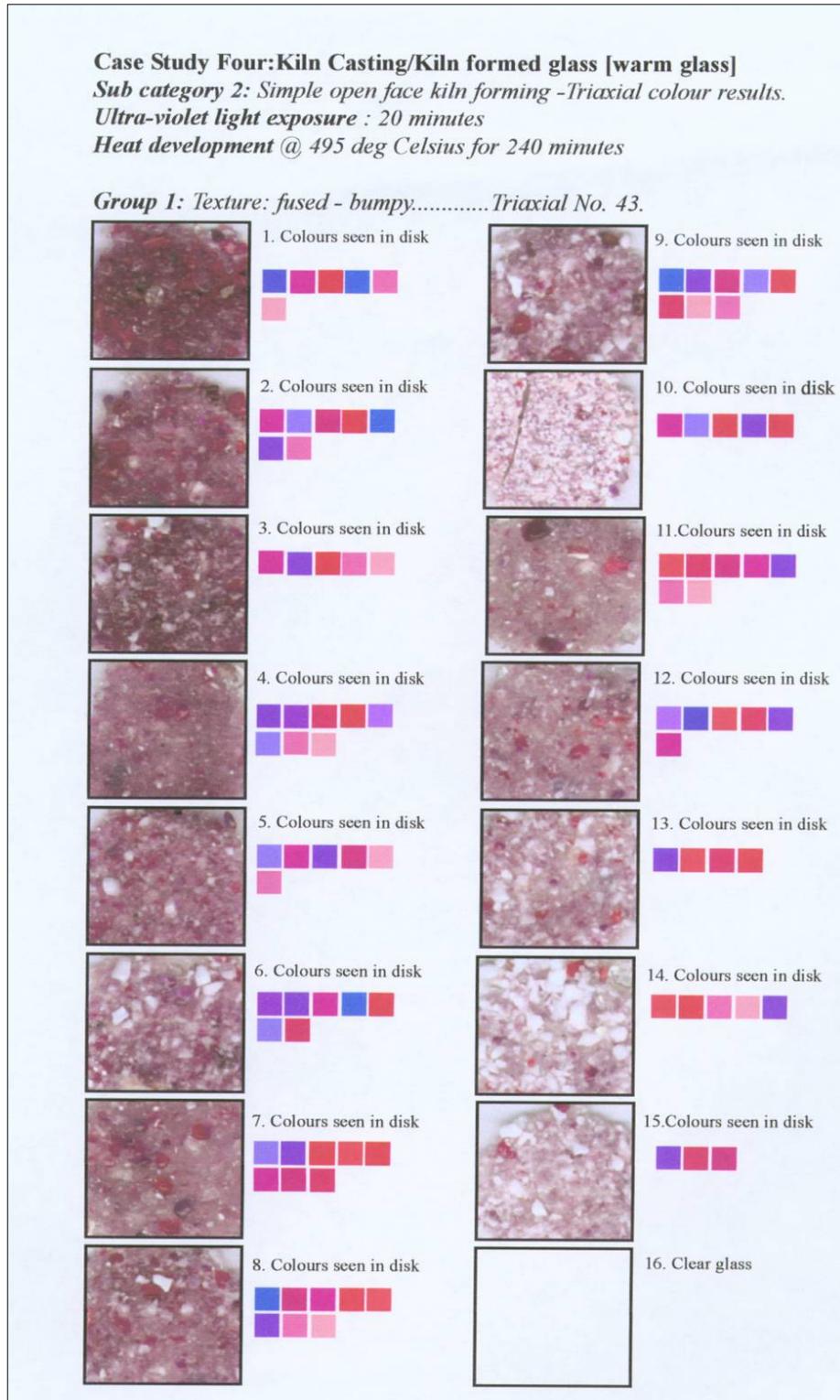
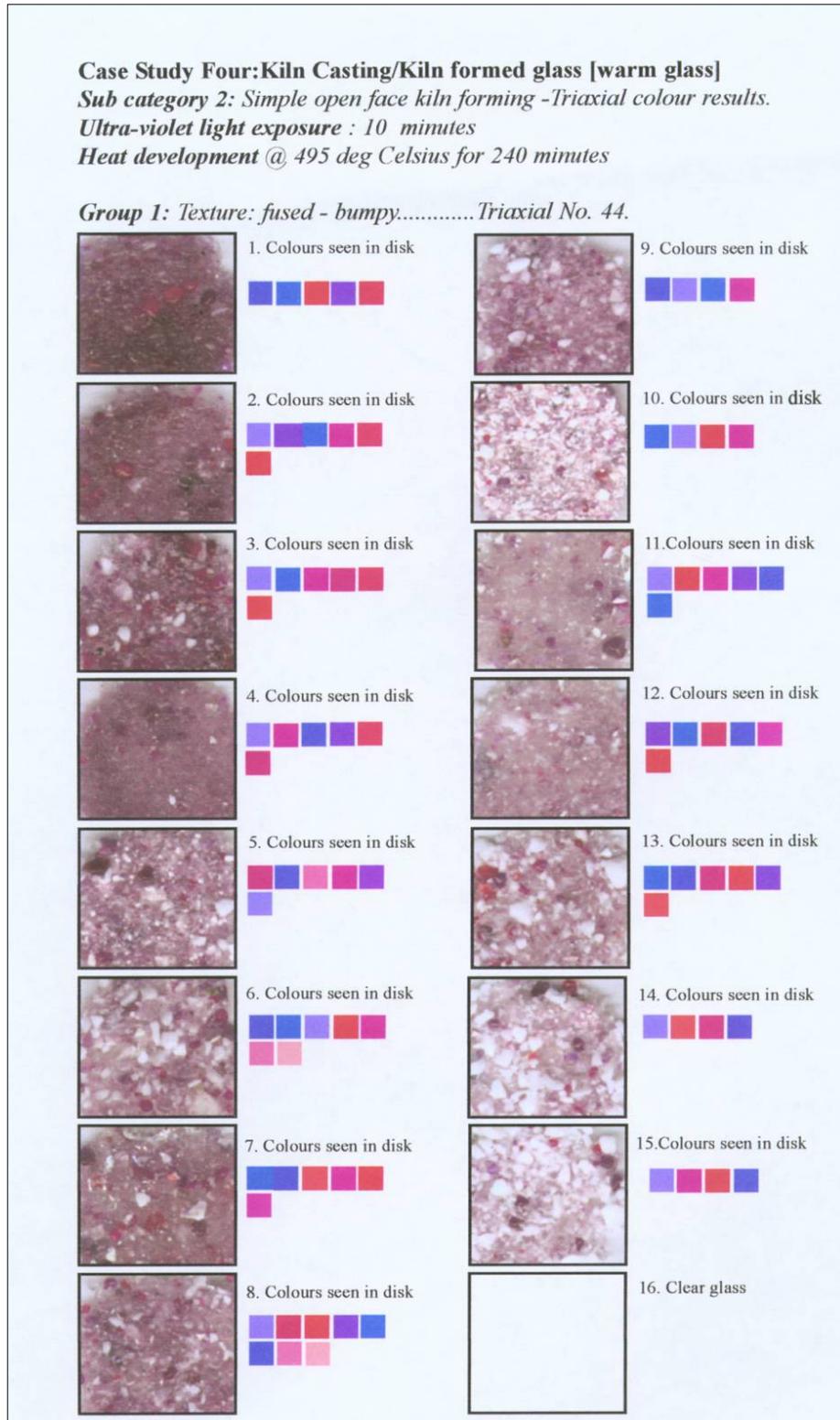


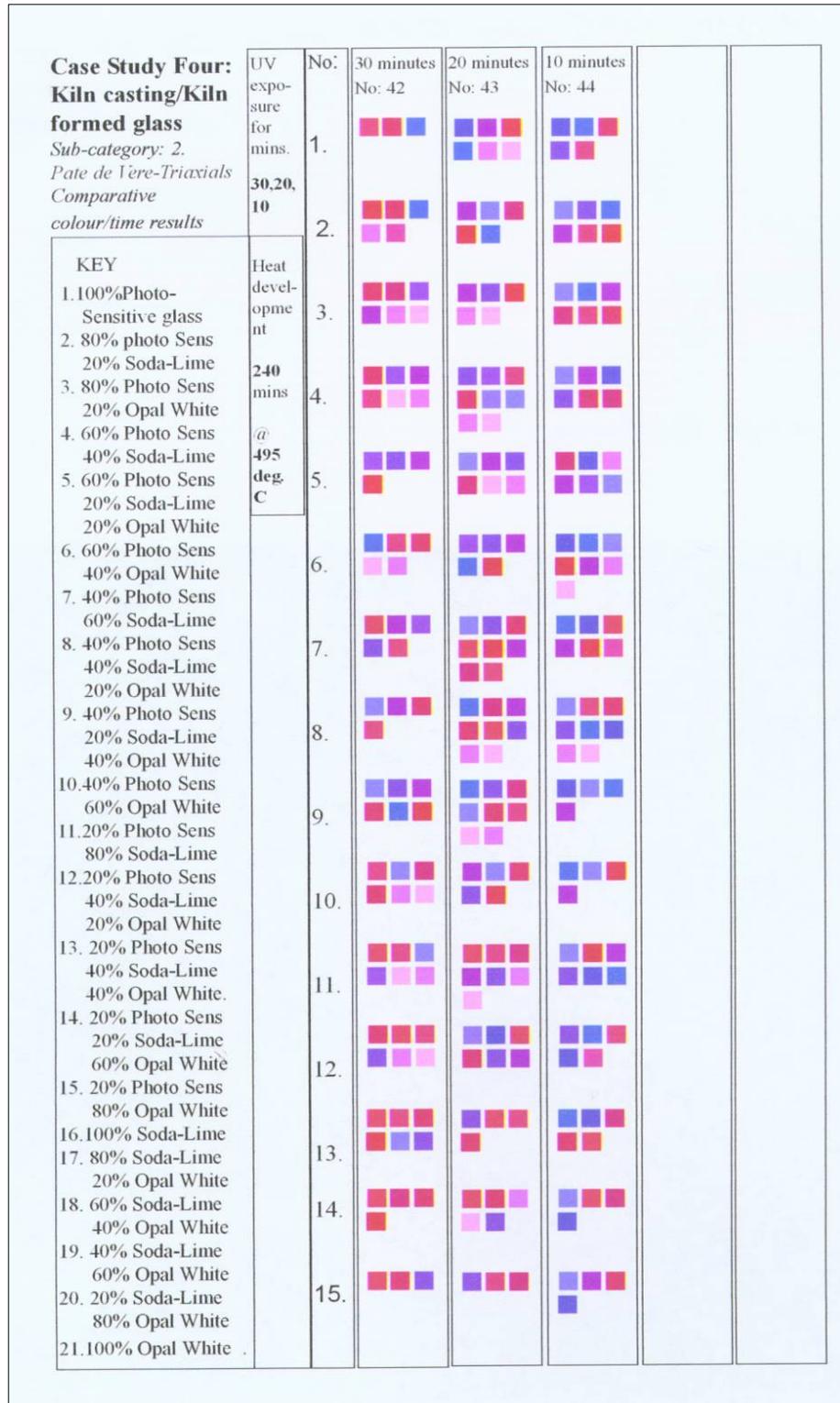
Figure 72c (Triaxial No: 44)



**Figure 72d** (Comparative timed UV exposure results)

<b>Case Study Four:</b> <b>Kiln Formed</b> <b>Photosensitive</b> <b>glass.</b> <i>Sub-category: 2.</i> <i>Pate de Verre-Triaxials</i> <i>Comparative UV expo-</i> <i>sure results</i>		Temp degrees Celsius	No:	Ultra violet light exposure times.			
				5 mins	10 mins	20 mins	30 mins
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White. 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	495	1.					
	2.						
	3.						
	4.						
	5.						
	6.						
	7.						
	8.						
	9.						
	10.						
	11.						
	12.						
	13.						
	14.						
	15.						
	240						

**Figure 72f** (Comparative colour/time results)



Section D: for 495 degrees Celsius for 90 minutes: Not attempted.

### **Analysis Figure 72**

Section D: 495 degree Celsius for 240 minutes developing time.

UV exposure:

- 5 minutes: Not attempted.
- 10 minutes No. 44: A good development of strong colours. 12 purple, 11 blue, 11 mauve, 8 violet, 11 cerise and 3 orange amongst the variety of reds, pin-reds, orange-reds and variety of pinks.
- 20 minutes No.43: A very good strong development of a variety of colours. 15 violet, 10 cerise, 6 orange, 5 blue and 2 purple seen amongst the red, red-pinks, orange-reds and variety of pinks.
- 30 minutes No.42: A moderate development of strong colours. 11 violet-colour, 7 mauves, 6 orange and 2 blue amongst the reds, orange-reds, red-pinks and variety of pinks.
- **Conclusion:** A good potential for development in a wide colour range when a stronger glass body is required.

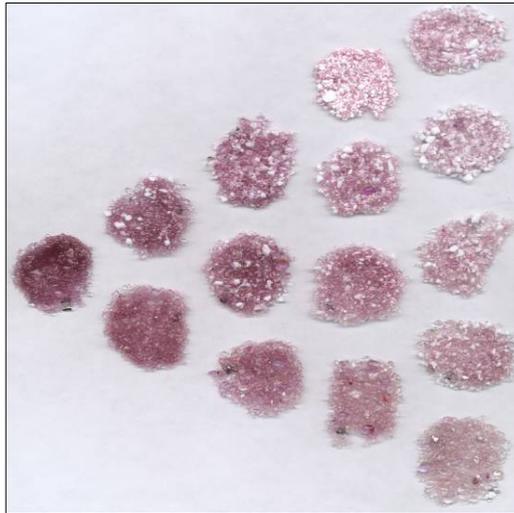
**Figure 73**

**Group 1: Section G**

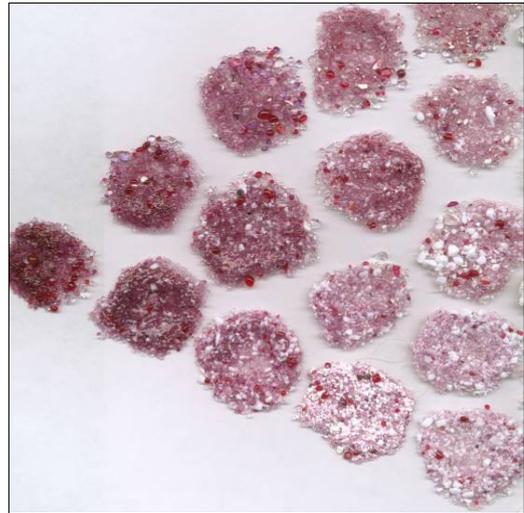
Temperature/Heat development range: @ 505 degrees Celsius

Time taken for colour development 90 minutes

Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 41.**  
UV exposure: 5 minutes  
Heat development: @ 505 degrees Celsius  
for 90 minutes.



**Triaxial No: 40.**  
UV exposure: 10 minutes  
Heat development: @ 505 degrees Celsius  
for 90 minutes.

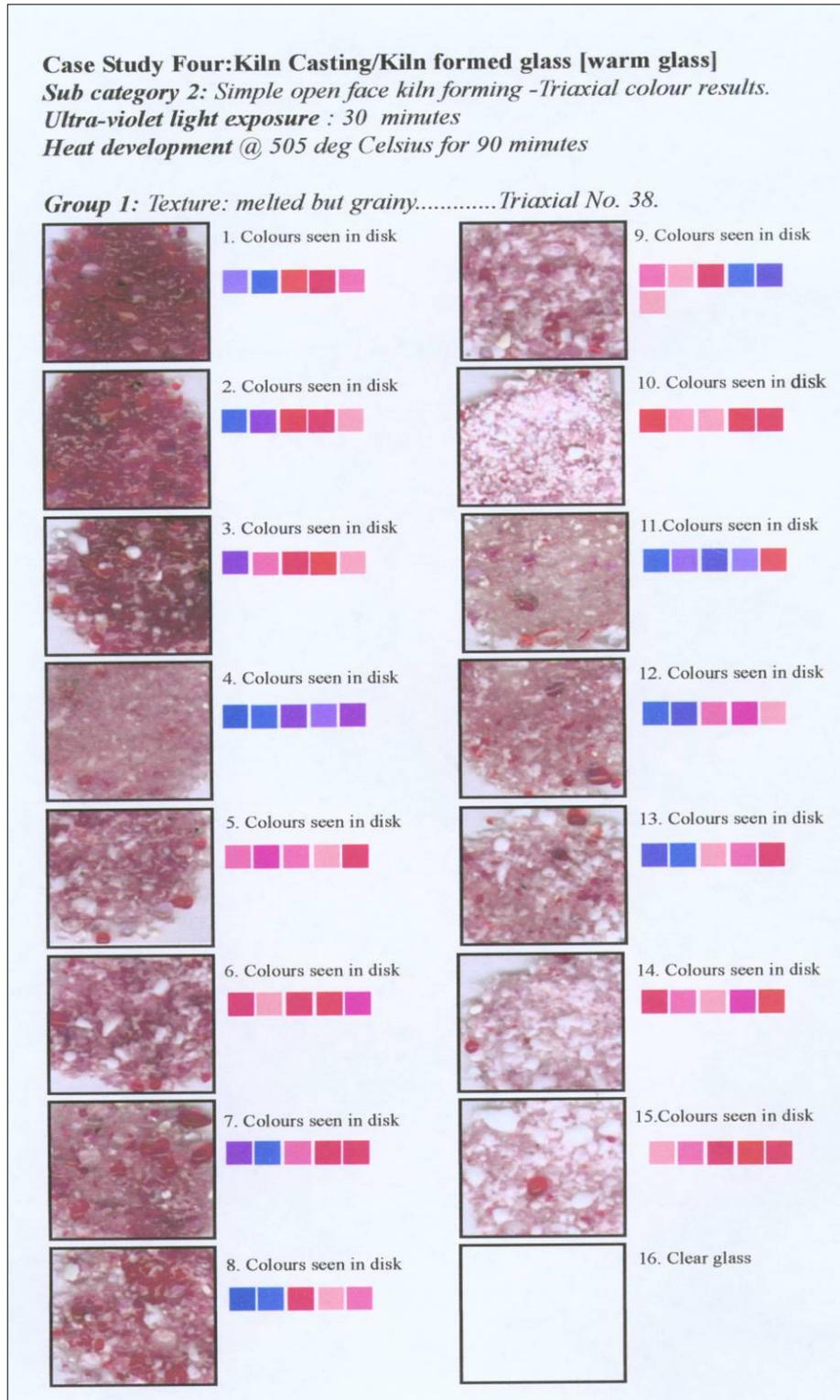


**Triaxial No: 39.**  
UV exposure: 20 minutes  
Heat development: @ 505 degrees Celsius  
for 90 minutes.



**Triaxial No: 38.**  
UV exposure: 30 minutes  
Heat development: @ 505 degrees Celsius  
for 90 minutes.

**Figure 73a** (Triaxial No: 38)



**Figure 73b** (Triaxial No: 39)

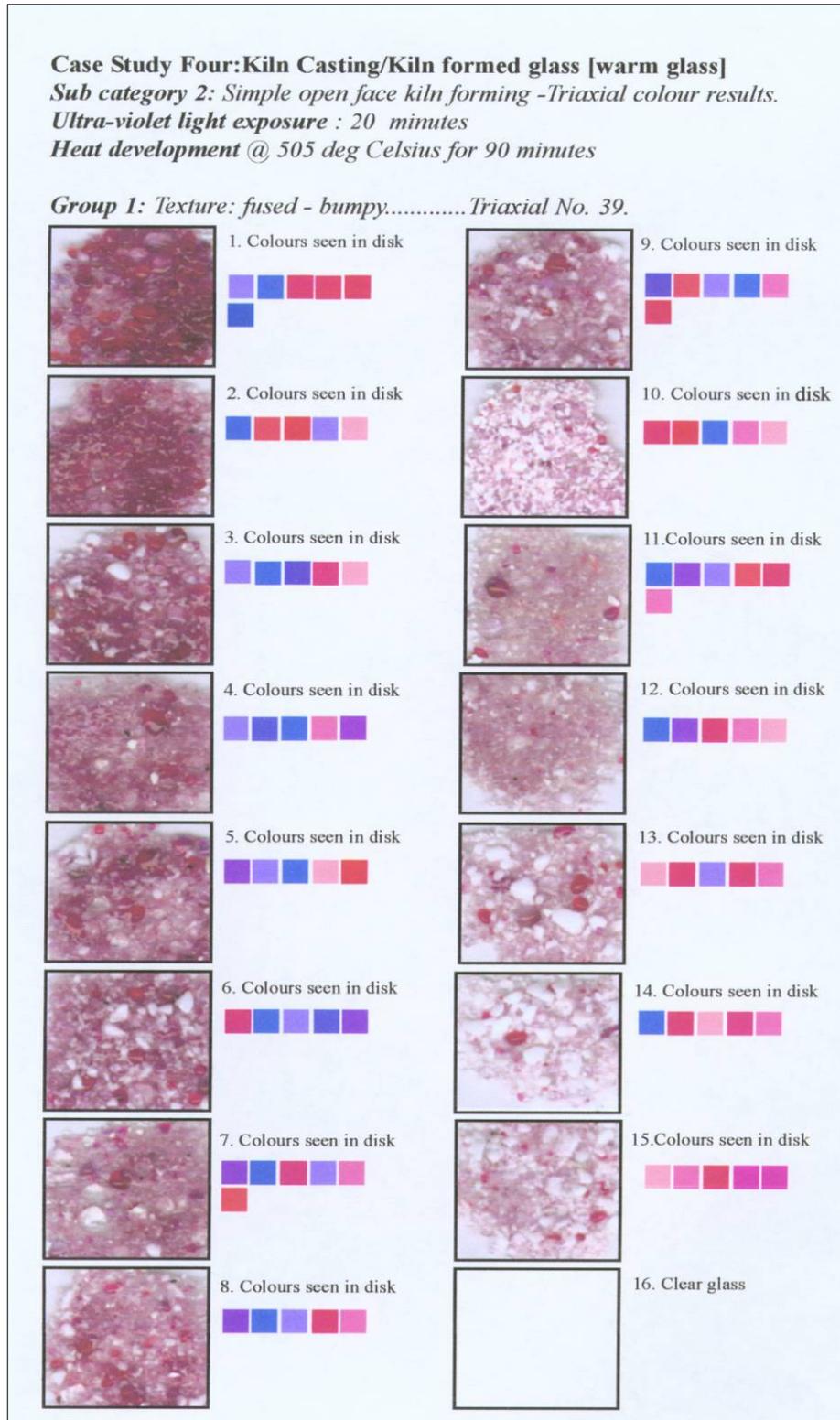
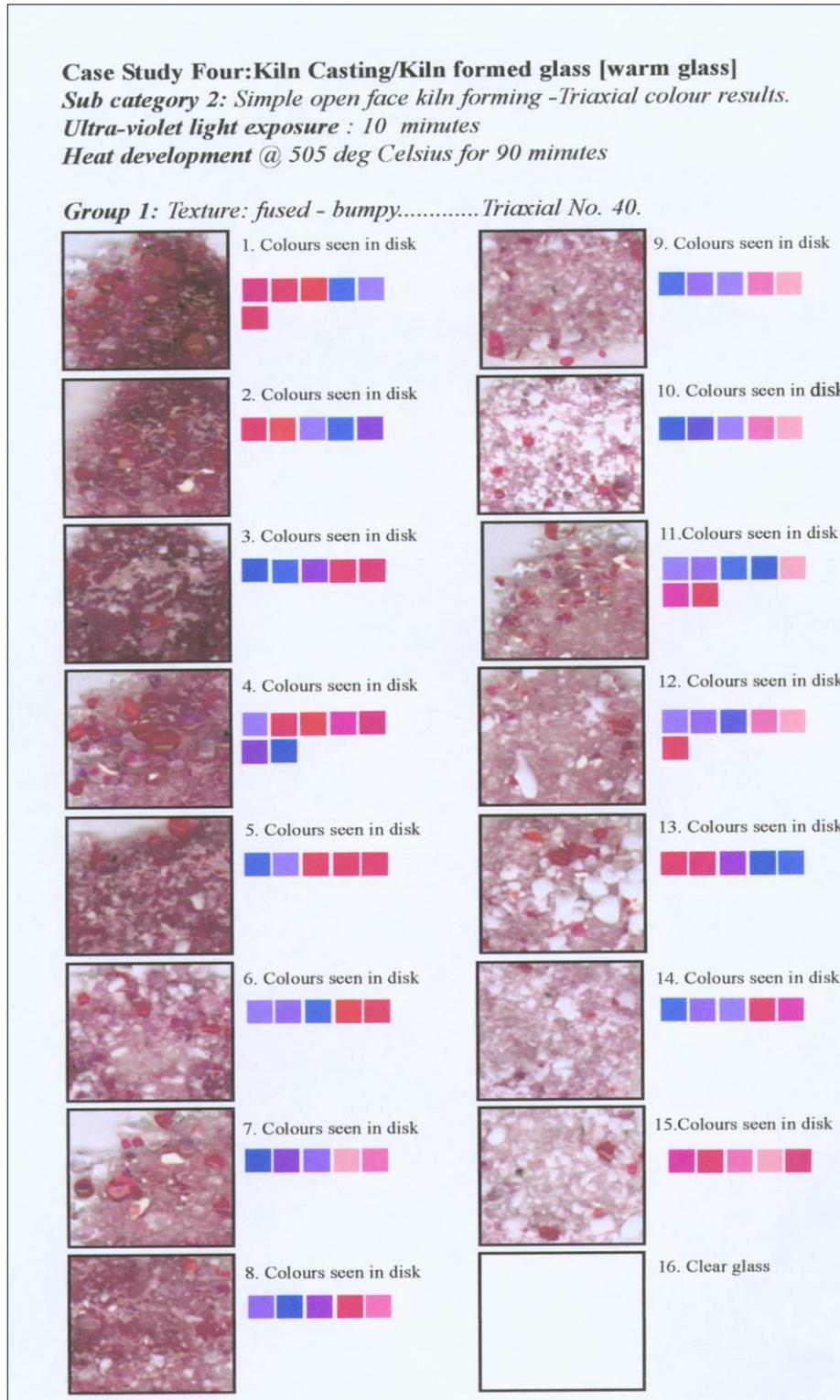
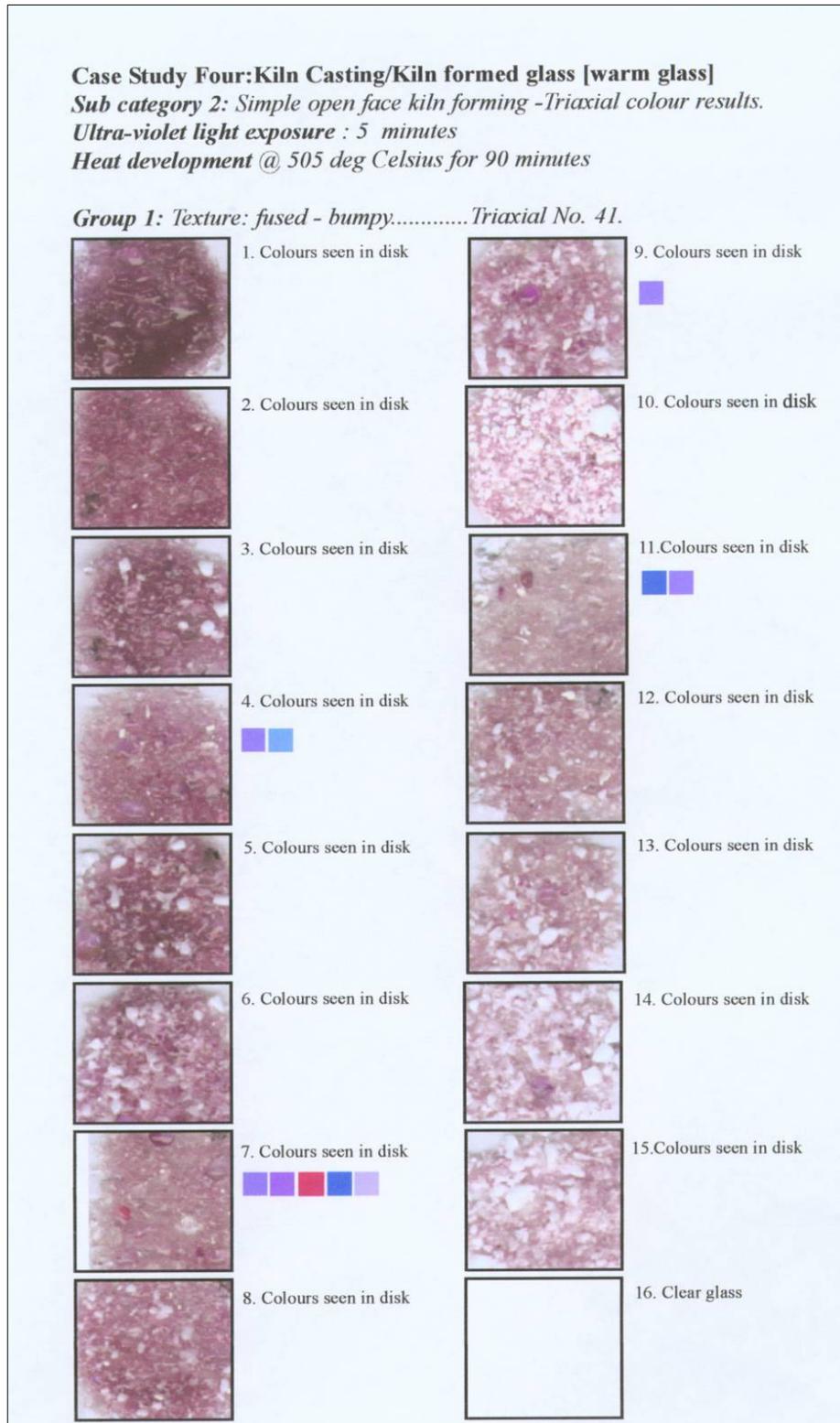


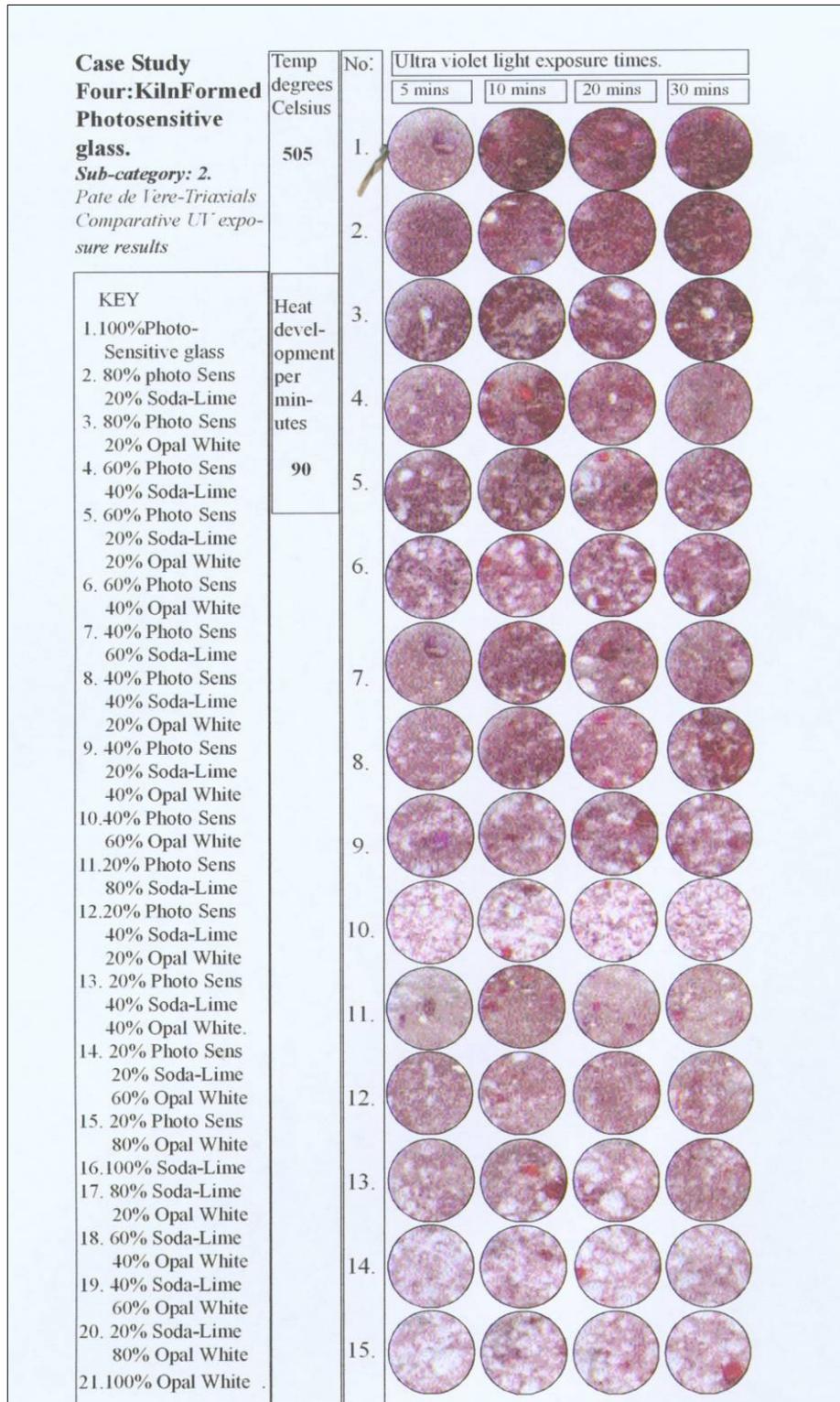
Figure 73c (Triaxial No: 40)



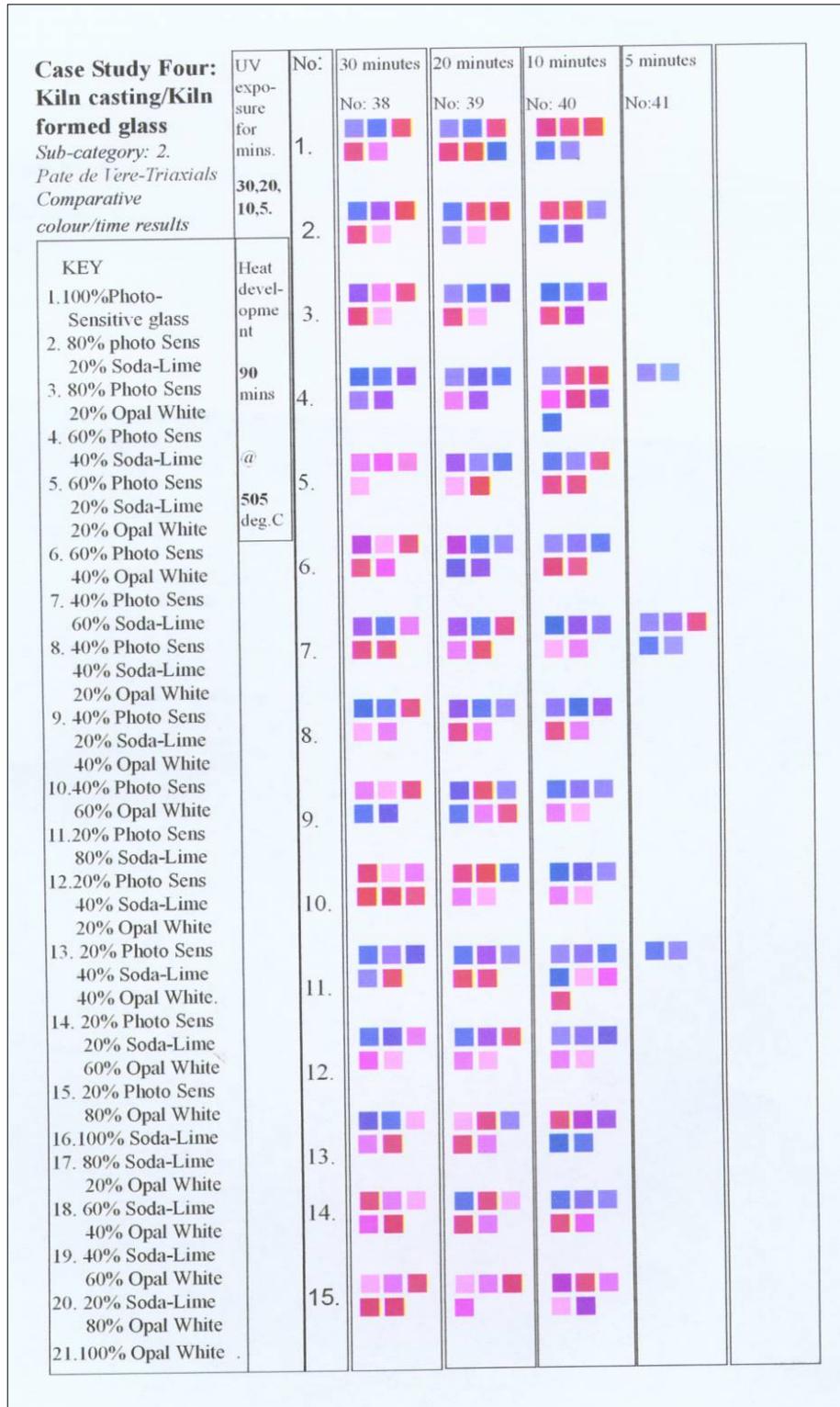
**Figure 73e** (Triaxial No: 41)



**Figure 73d** (Comparative timed UV exposure results)



**Figure 73f** (Comparative colour/time results)



### **Analysis Figure 73**

Section G: for 505 degrees Celsius for 90 minutes developing time.

UV exposure:

- 5 minutes No. 41: A sparse colour development showing mauve and blue in disks 4m 7 and 11.
- 10 minutes No.40: A good development of strong colours. 17 mauves, 16 blue, 6 violet and 3 cerise seen amongst the variety of reds, pink-reds, orange-reds and variety of pinks.
- 20 minutes No. 39: A moderate development of strong colours. 14 blues, 11 mauves, 7 violet and 3 orange seen amongst the reds, pink-reds, orange-reds and variety of pinks.
- 30 minutes No 38: A moderate development of strong colours. 11 blues, 5 violet, 4 purples, 4 mauves and 1 orange seen amongst the reds- pink-reds, orange-reds and variety of pinks.
- **Conclusion:** Moderate Potential.

**Figure 74**

**Group 1: Section H**

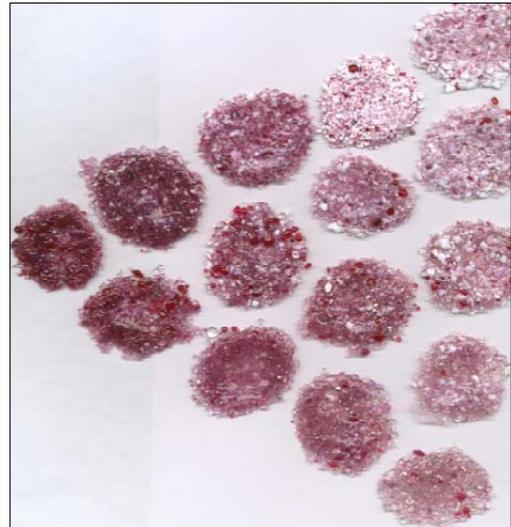
Temperature/Heat development range: @ 505 degrees Celsius

Time taken for colour development 120 minutes

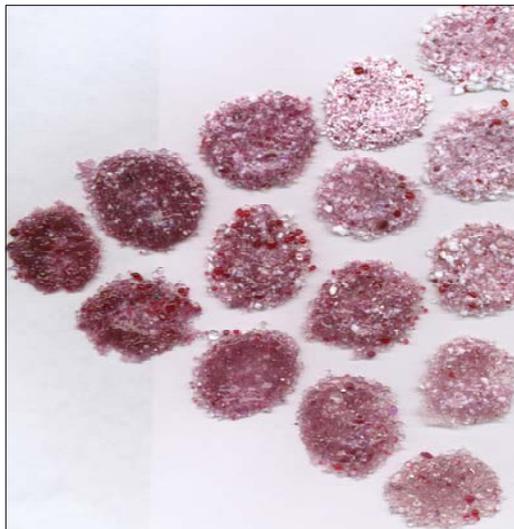
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 37.**  
UV exposure: 5 minutes  
Heat development: @ 505 degrees Celsius  
for 120 minutes.



**Triaxial No: 36**  
UV exposure: 10 minutes  
Heat development: @ 505 degrees Celsius  
for 120 minutes.

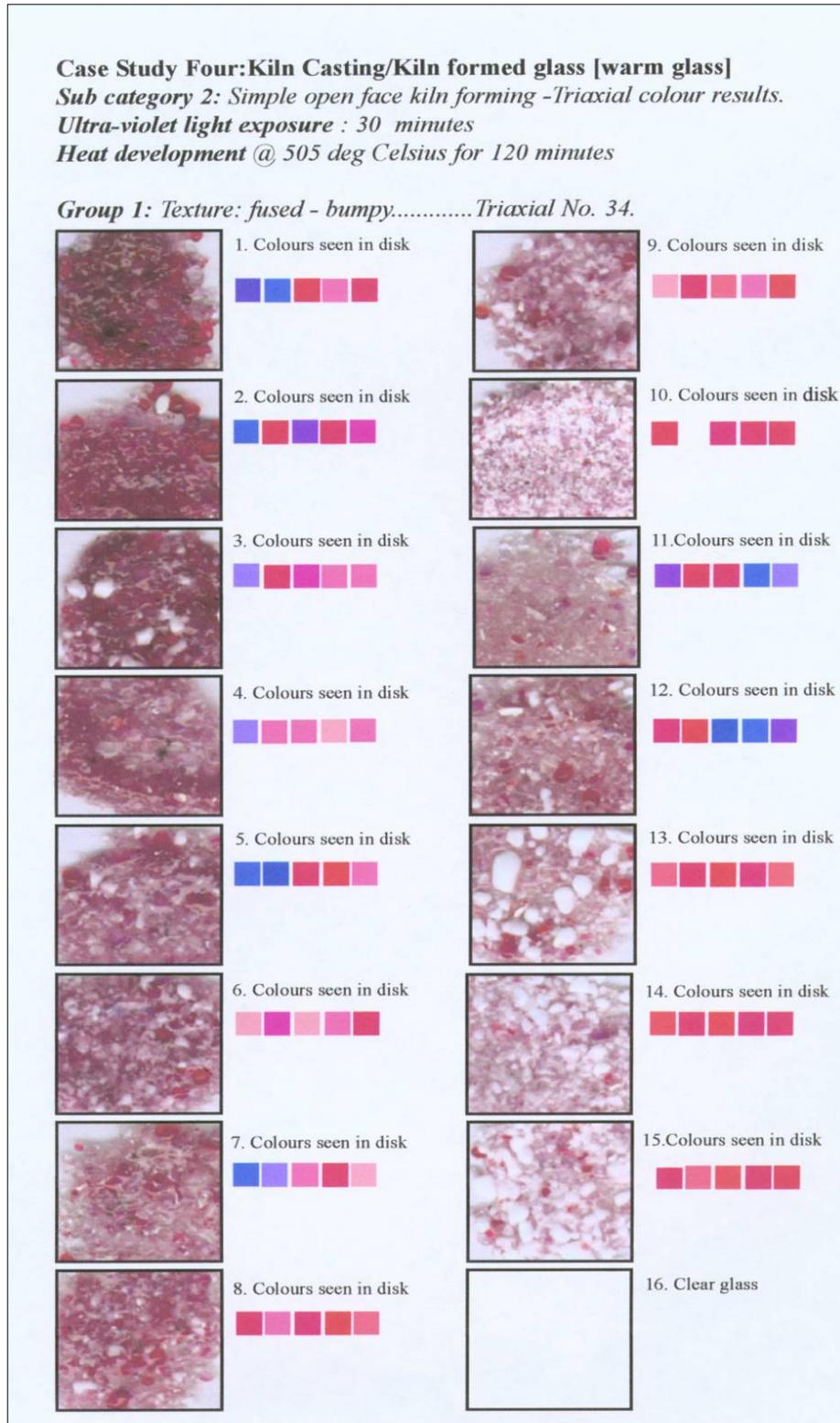


**Triaxial No: 35.**  
UV exposure: 20 minutes  
Heat development: @ 505 degrees Celsius  
for 120 minutes.



**Triaxial No: 34.**  
UV exposure: 30 minutes  
Heat development: @ 505 degrees Celsius  
for 120 minutes.

Figure 74a (Triaxial 34)



**Figure 74b** (Triaxial No: 35)

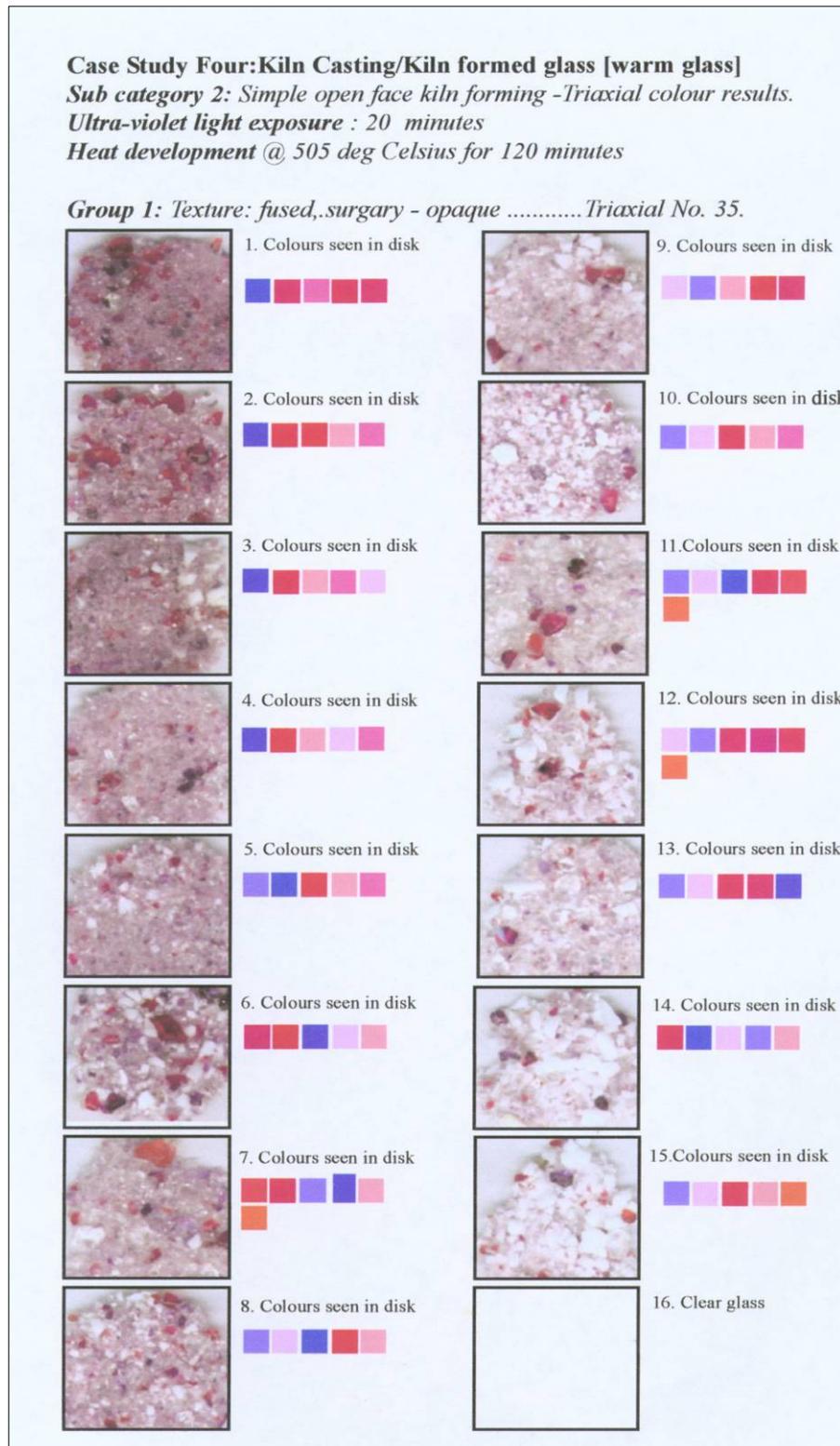
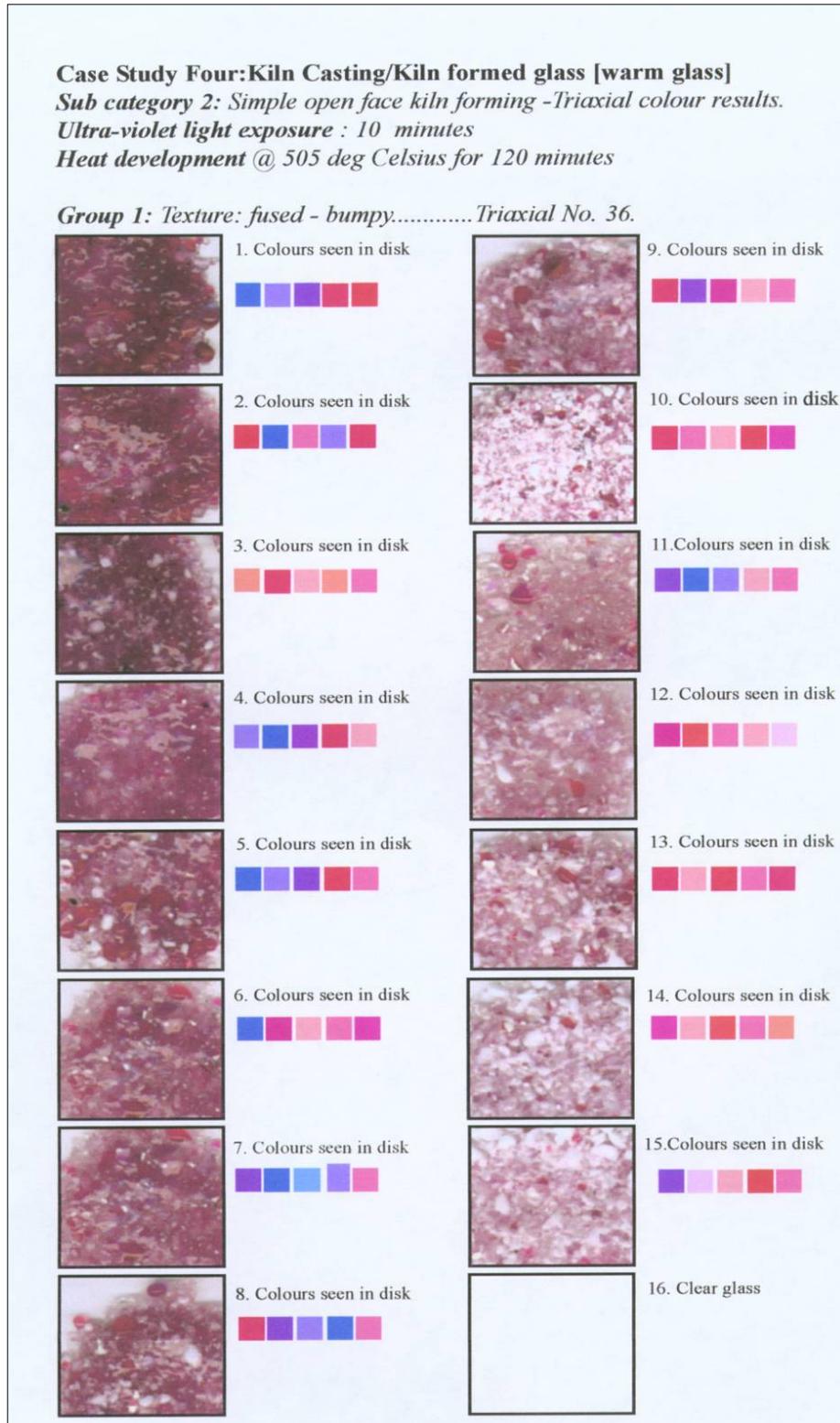
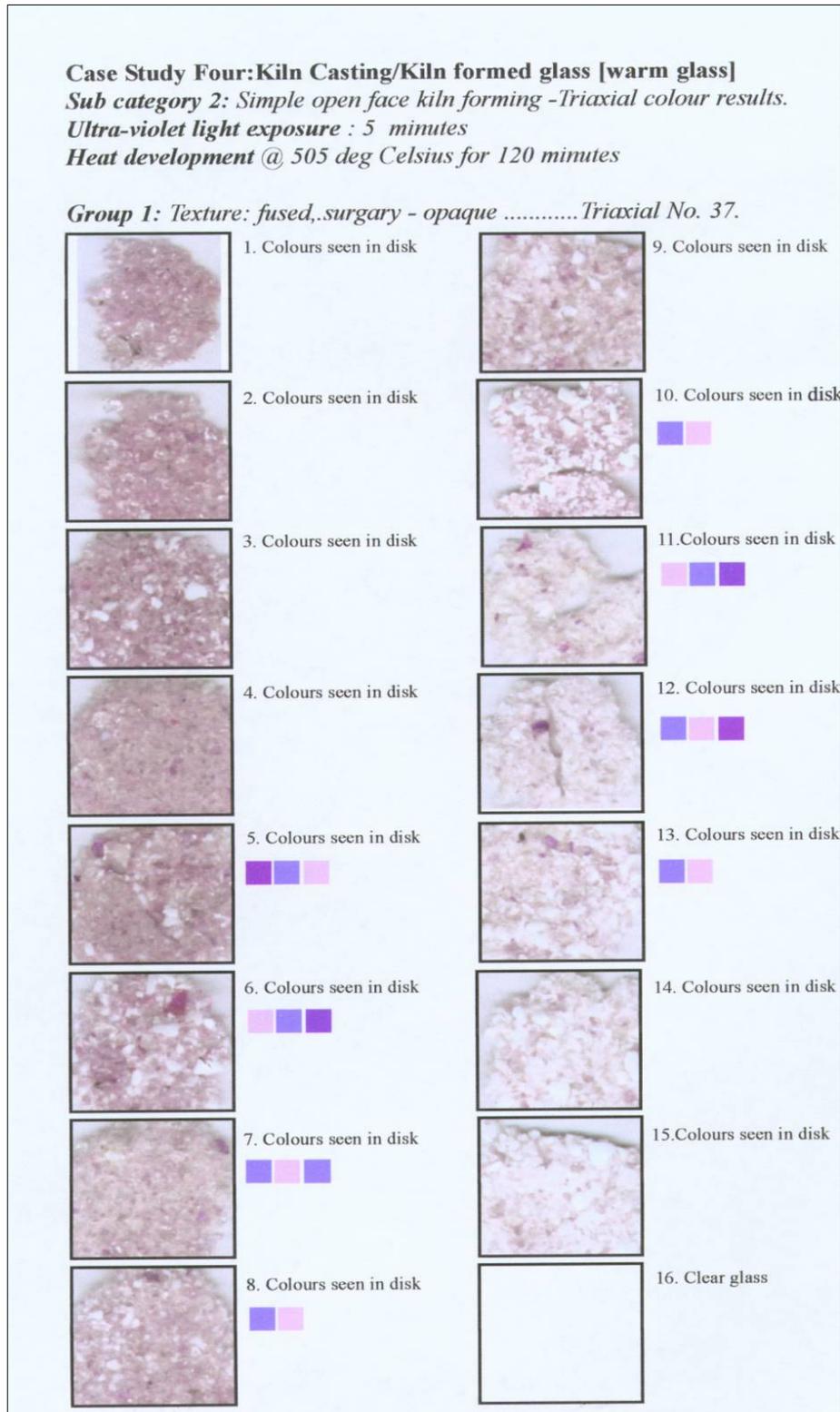


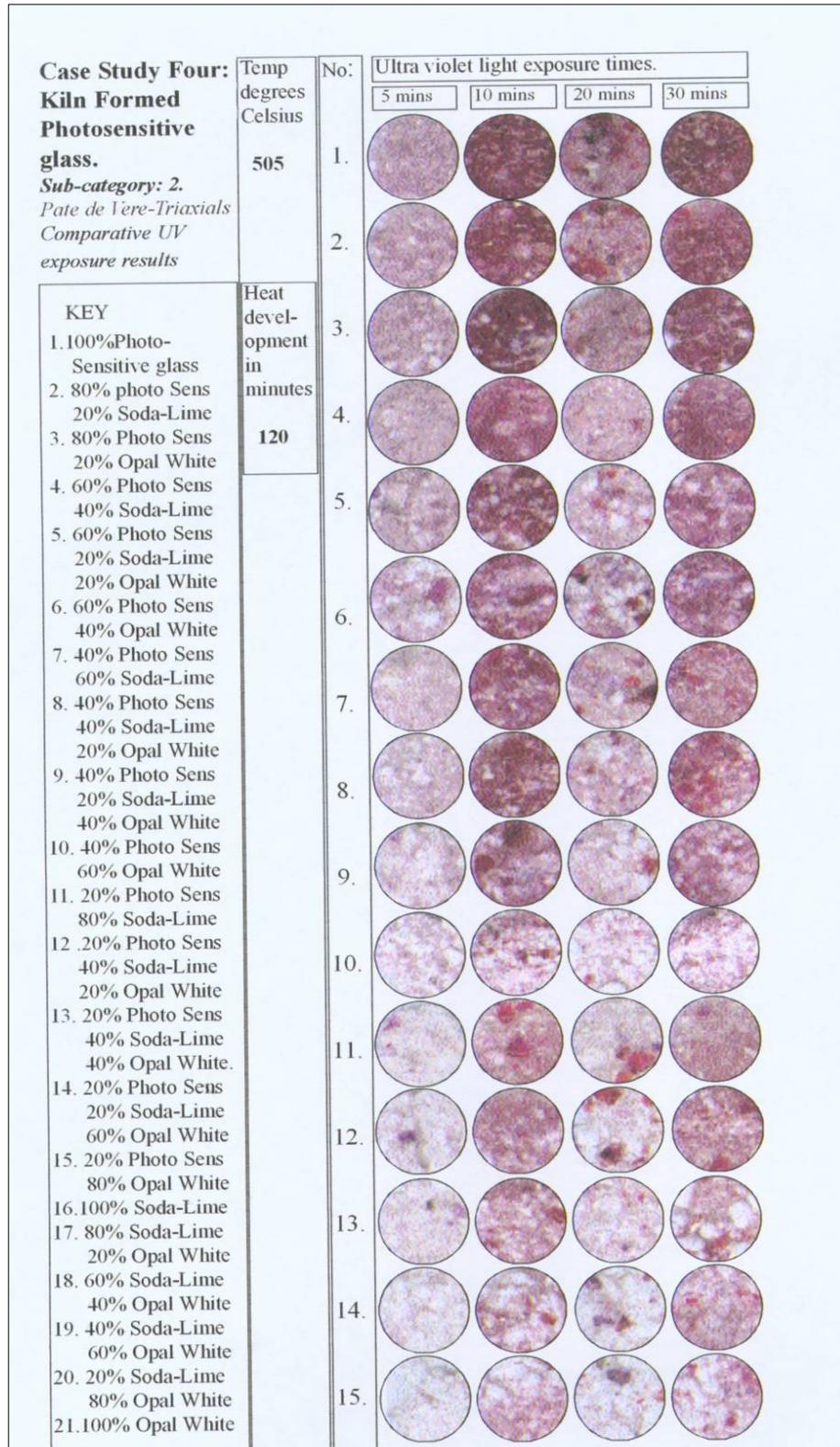
Figure 74c (Triaxial No: 36)



**Figure 74e** (Triaxial No: 37)



**Figure 74d** (Comparative timed UV exposure results)



**Figure 74f** (Comparative colour/time results)

<b>Case Study Four: Kiln casting/Kiln formed glass</b> <i>Sub-category: 2. Pate de Verre-Triaxials Comparative colour/time results</i>		UV expo- sure for mins.	No:	30 minutes	20 minutes	10 minutes	5 minutes
<b>KEY</b> 1. 100%Photo-Sensitive glass 2. 80% photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	Heat devel- opment	30,20, 10,5	No: 34	No: 35	No: 36	No: 37	
	@ 505 deg.C	120 mins	1.				
			2.				
			3.				
			4.				
			5.				
			6.				
			7.				
			8.				
			9.				
			10.				
			11.				
			12.				
			13.				
			14.				
			15.				

## Analysis Figure 74

Section H: for 505 degrees Celsius for 120 minutes developing time.

- UV exposure:
- 5 minutes No 37: Eight disks showed early colour development. The colours mauve, mauve-pink, and violet-pink can be seen in disks 5,6,7,8,10,11,12 and 13.
- 10 minutes No.36: A moderate development of some strong colours and some pales colours. 9 blue, 7 mauves, 2 mauve-pinks, 8 violet appear amongst the variety of reds, pink-reds, orange-reds, orange-pinks and variety of pinks.
- 20 minutes No. 35: A moderate development of some strong colours and some paler colours. 11 purples, 16 mauve-pinks and 5 orange can be seen amongst the reds, pink-reds, orange-reds and pale pinks.
- 30 minutes No.34: A moderate development of strong colours. 7 blue, 3 violets, 4 mauves, 1 purple, 1 salmon-pink and 2 orange were seen amongst the reds, pink-reds, orange-reds and variety of pinks.
- **Conclusion:** A moderate potential for colour development at 10 and 20 minutes UV exposure.

**Figure 75**

**Group 1: Section I**

Temperature/Heat development range: @ 505 degrees Celsius

Time taken for colour development 180 minutes

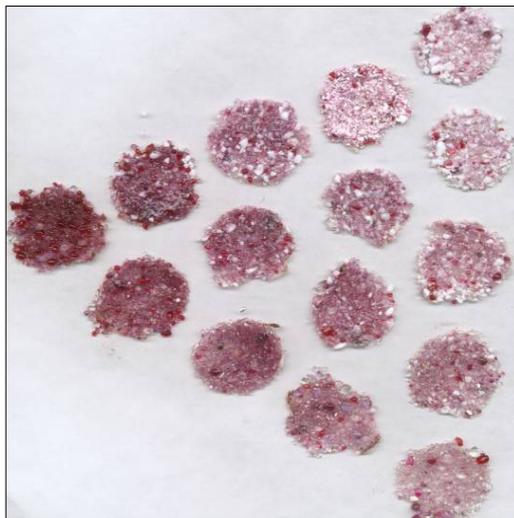
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 33.**  
UV exposure: 5 minutes  
Heat development: @ 505 degrees Celsius  
for 181 minutes.



**Triaxial No: 32.**  
UV exposure: 10 minutes  
Heat development: @ 505 degrees Celsius  
for 181 minutes.

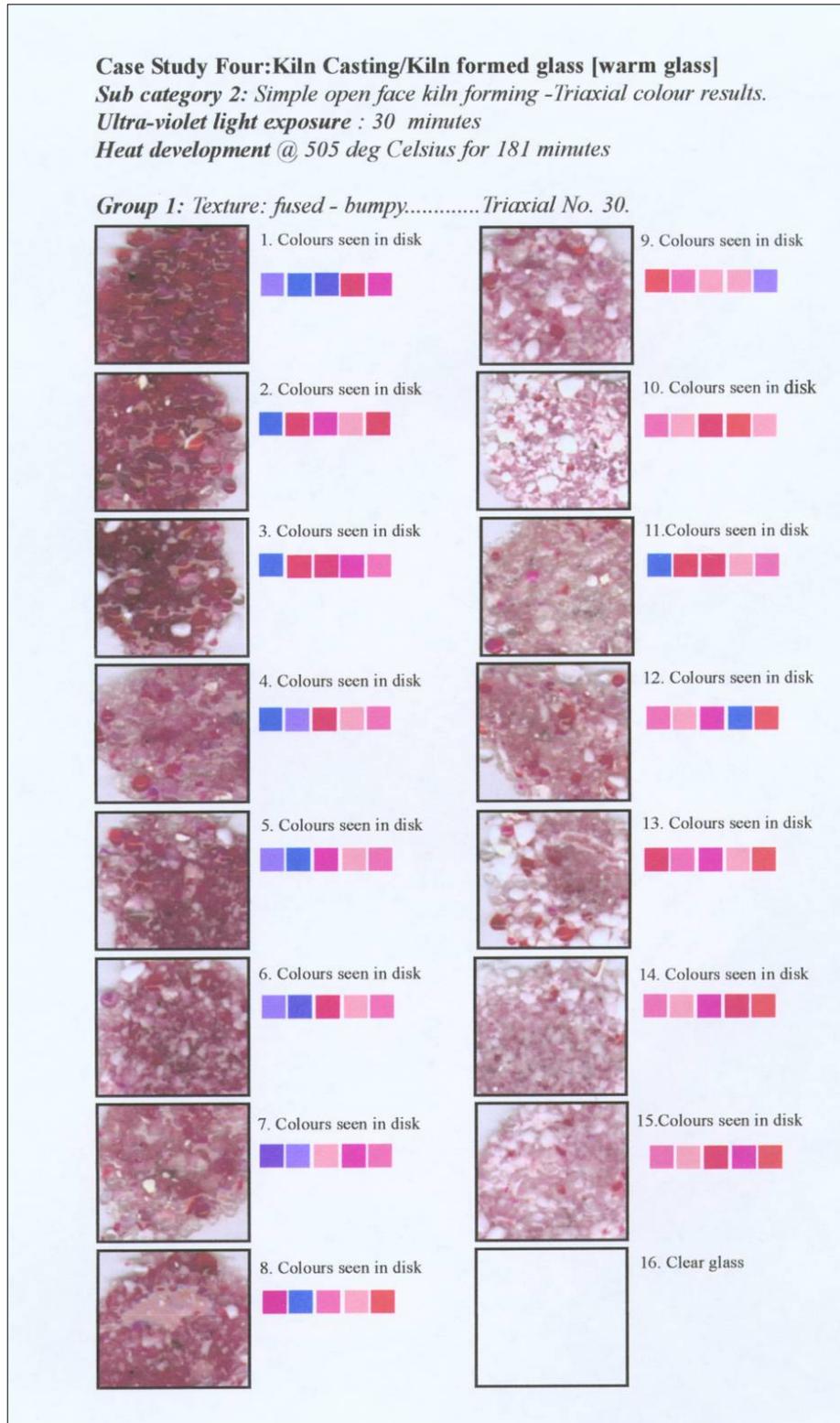


**Triaxial No: 31.**  
UV exposure: 20 minutes  
Heat development: @ 505 degrees Celsius  
for 181 minutes.



**Triaxial No: 30.**  
UV exposure: 30 minutes  
Heat development: @ 505 degrees Celsius  
for 181 minutes.

**Figure 75a** (Triaxial No: 30)



**Figure 75b** (Triaxial No:31)

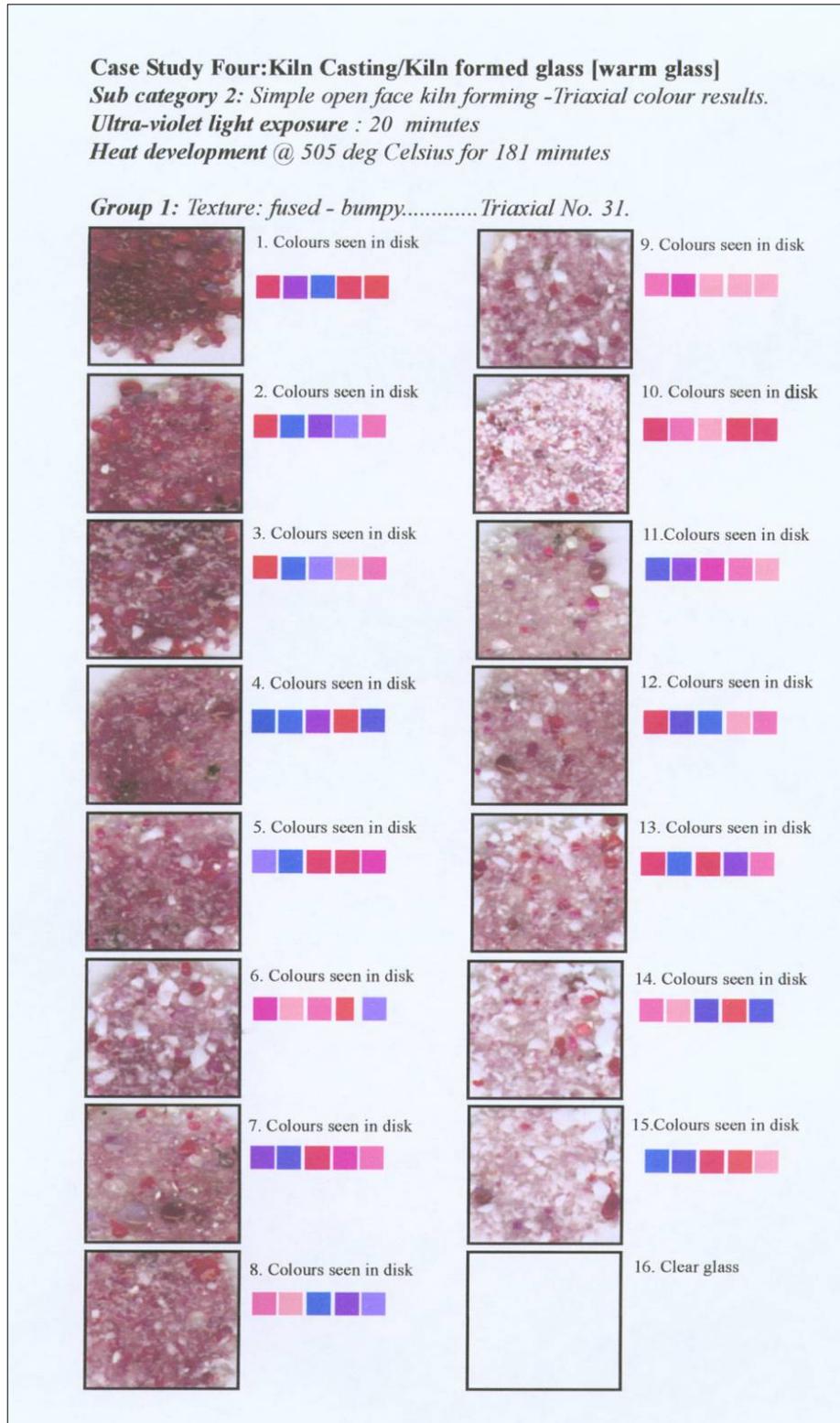
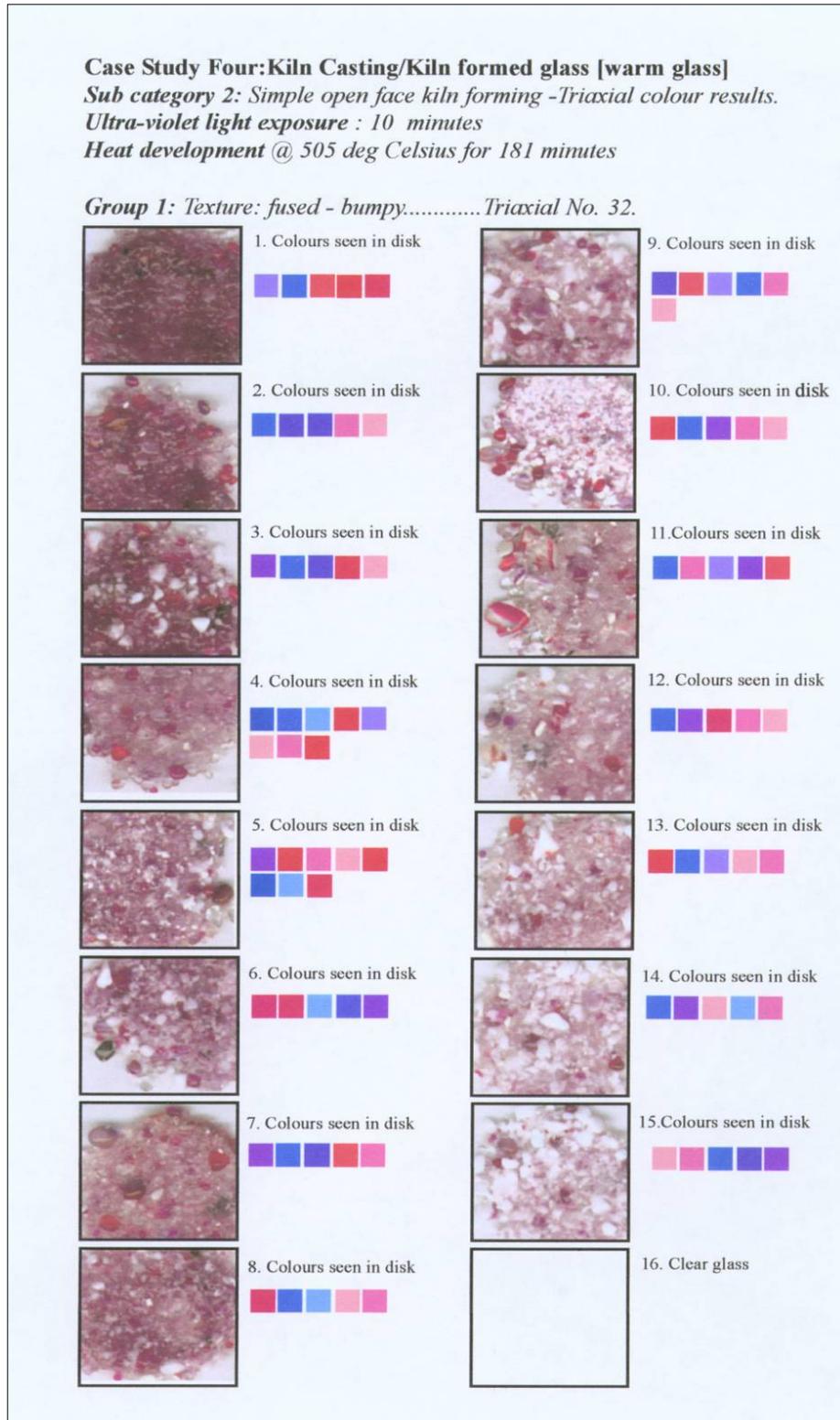
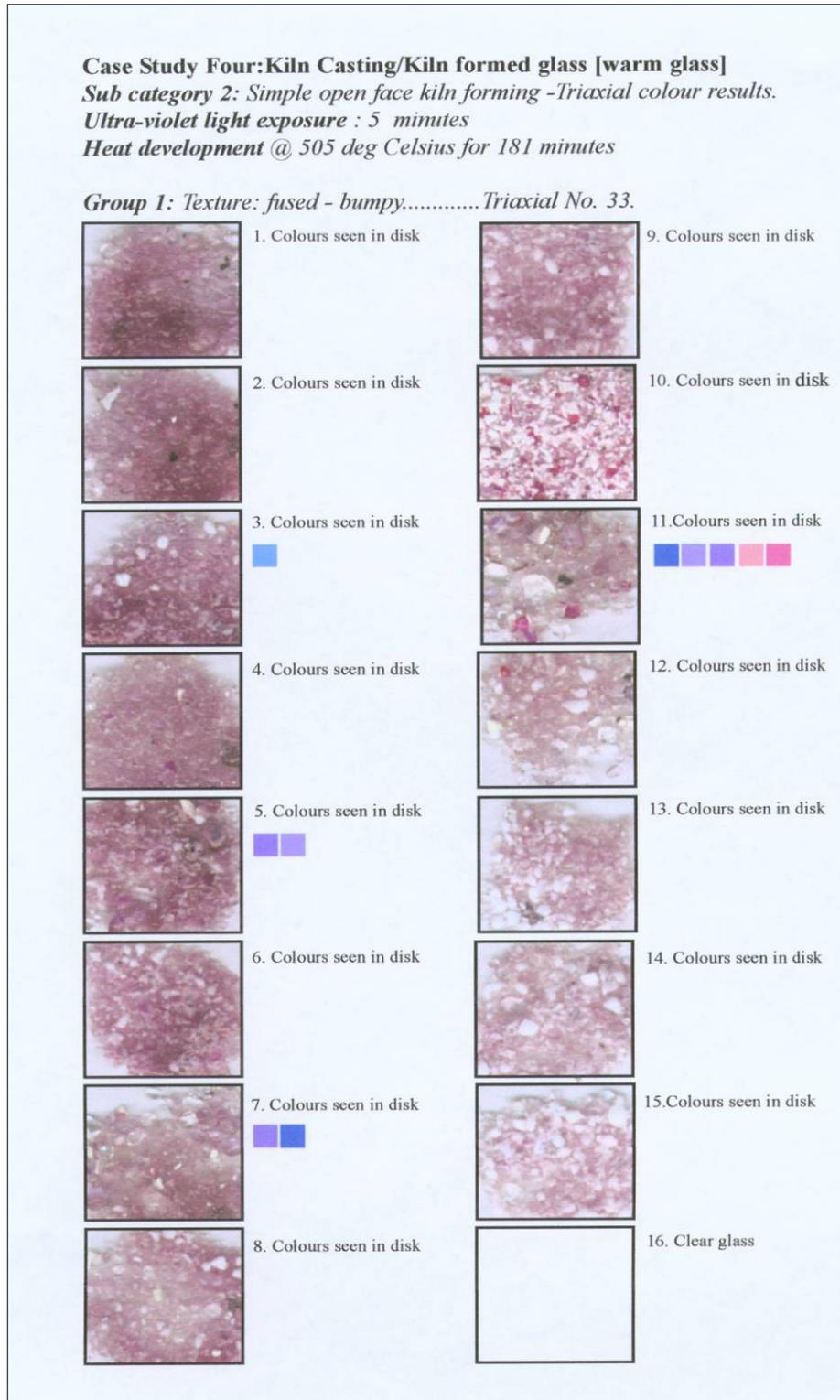


Figure 75c (Triaxial No: 32)



**Figure 75e** (Triaxial No: 33)



**Figure 75d** (Comparative timed UV exposure results)

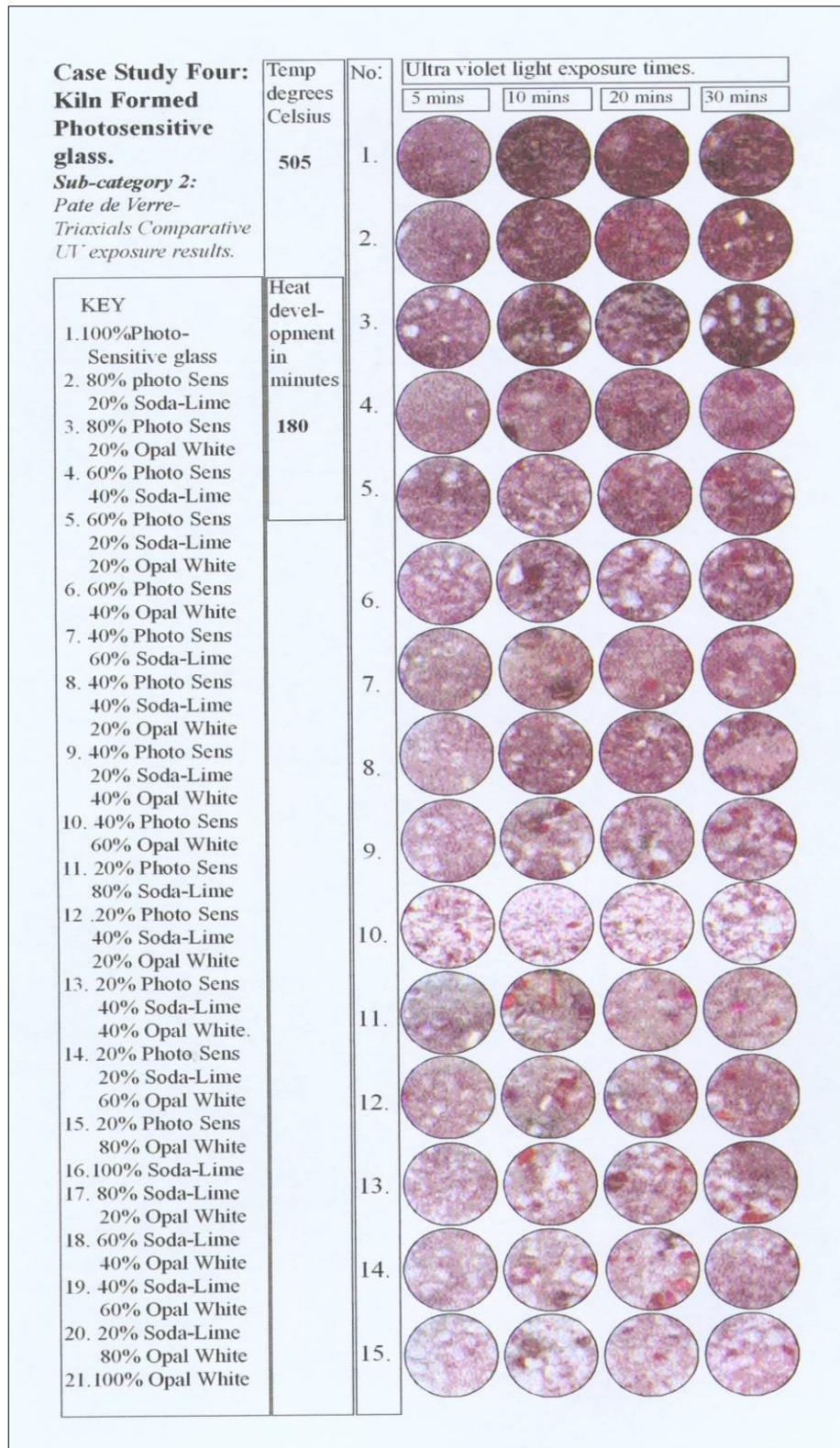
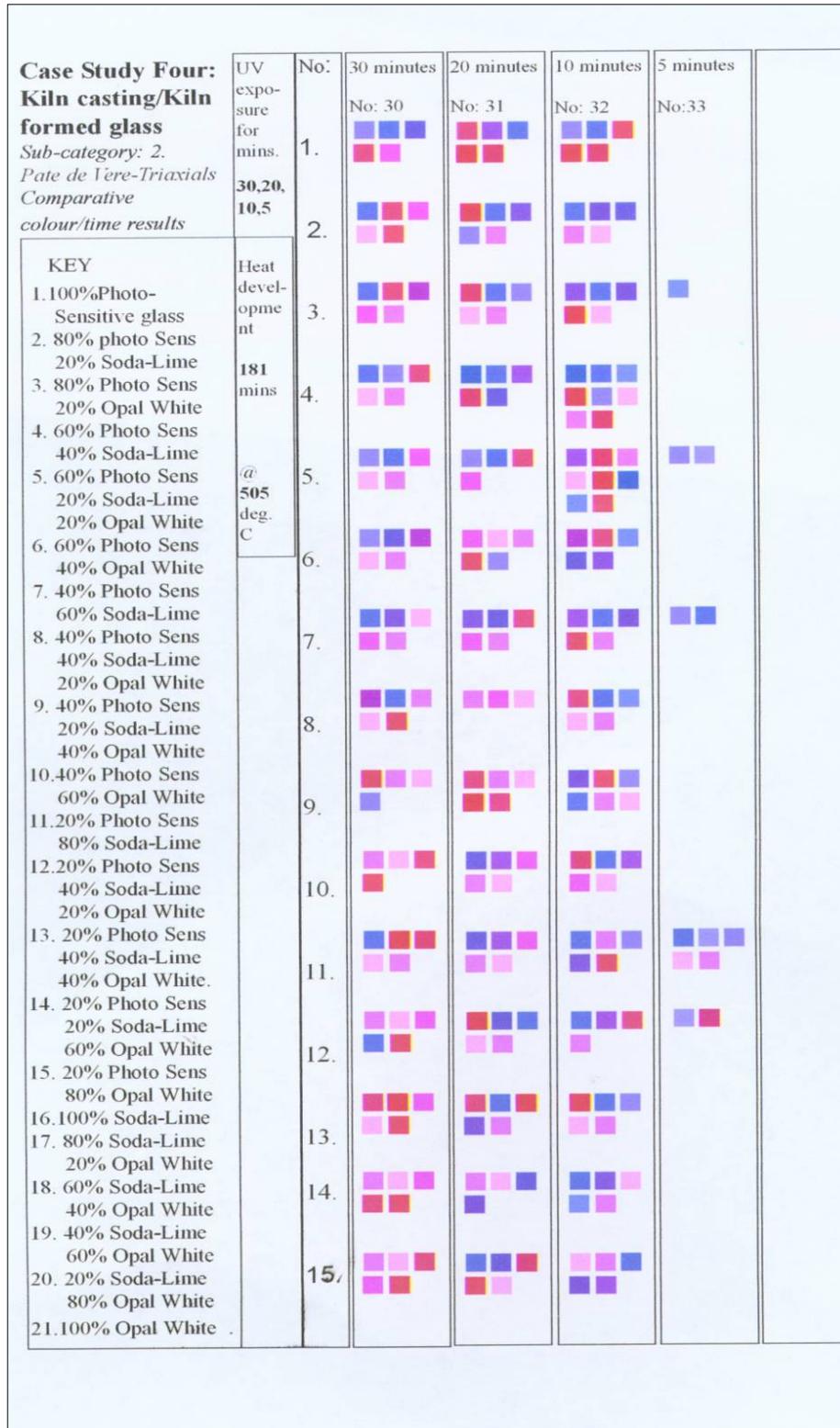


Figure 75f (Comparative colour/time results)



## Analysis Figure 75

Section I: for 505 degrees Celsius for 180 minutes developing time.

- **UV exposure:**
- **5 minutes No.33:** A very low and limited colour development in only 5 disks showing mainly pale-mauve, light-blue and some pinks.
- **10 minutes No.32:** A good development showing a colour range of 18 blue, 9 violet, 6 purple, 5 mauve and 4 orange that were seen amongst the reds, orange-reds, cerise, and variety of pinks.
- **20 minutes No.31:** A moderate colour development showing fewer colours. 10 blue, 7 violet, 4 purple, 5 mauve and 3 orange amongst the reds, orange-reds, orange-pinks and variety of pinks.
- **30 minutes No.30:** A moderate colour development. Fewer colours seen. 8 blue, 2 purple, 6 mauves and 5 orange amongst the orange-pinks, cerise and variety of pinks.
- **Conclusion:** Moderate potential for colour development at UV exposure of 10 and 20 minutes.

**Group 2** was divided into sections according to the length of time it took to develop the colours at the ultraviolet light exposure times of 5 minutes, 10 minutes, 20 minutes and 30 minutes at the heat development times of 90, 120, 180 and 240 minutes at the temperature of 525 degrees Celsius. Control triaxial No.2. UV exposure: None. Heat development @ 525 degrees Celsius for 120 minutes. Triaxial No. 16 is not printed in the following tables due to the fact that the heat development @ 525 degrees Celsius for 300 minutes melted the photosensitive glass into a smooth dull red.

**Figure 76**

**Group 2: Section J**

Temperature/Heat development range: @ 525 degrees Celsius

Time taken for colour development 90 minutes

Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



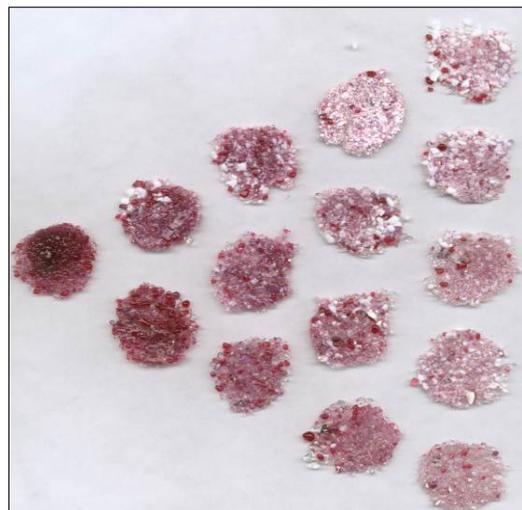
**Triaxial No: 29.**  
UV exposure: 5 minutes  
Heat development: @ 525 degrees Celsius  
for 90 minutes.



**Triaxial No: 28.**  
UV exposure: 10 minutes  
Heat development: @ 525 degrees Celsius  
for 90 minutes.

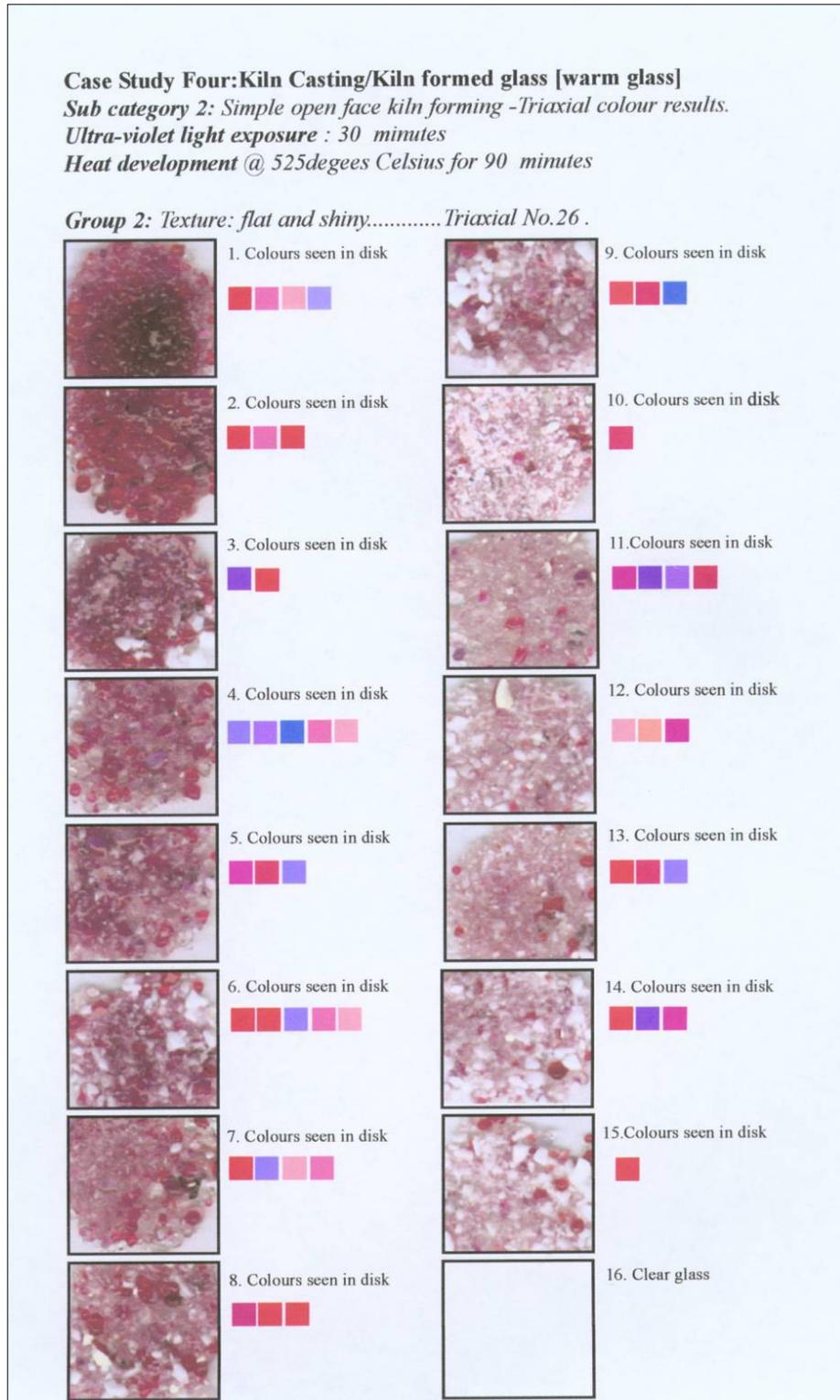


**Triaxial No: 27.**  
UV exposure: 20 minutes  
Heat development: @ 525 degrees Celsius  
for 90 minutes.



**Triaxial No: 26.**  
UV exposure: 30 minutes  
Heat development: @ 525 degrees Celsius  
for 90 minutes.

**Figure 76a** (Triaxial No.26)



**Figure 76b** (Triaxial No. 27)

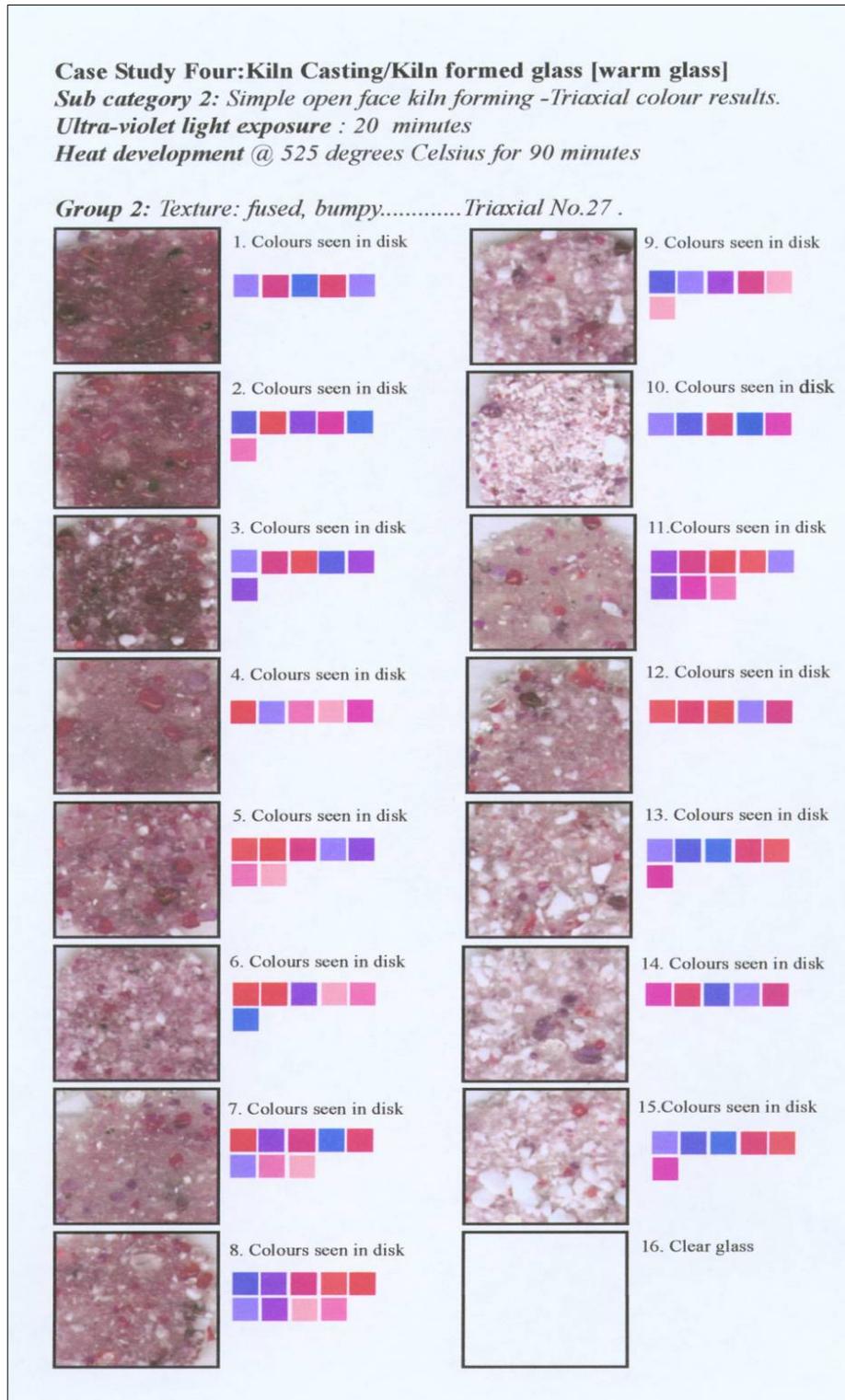
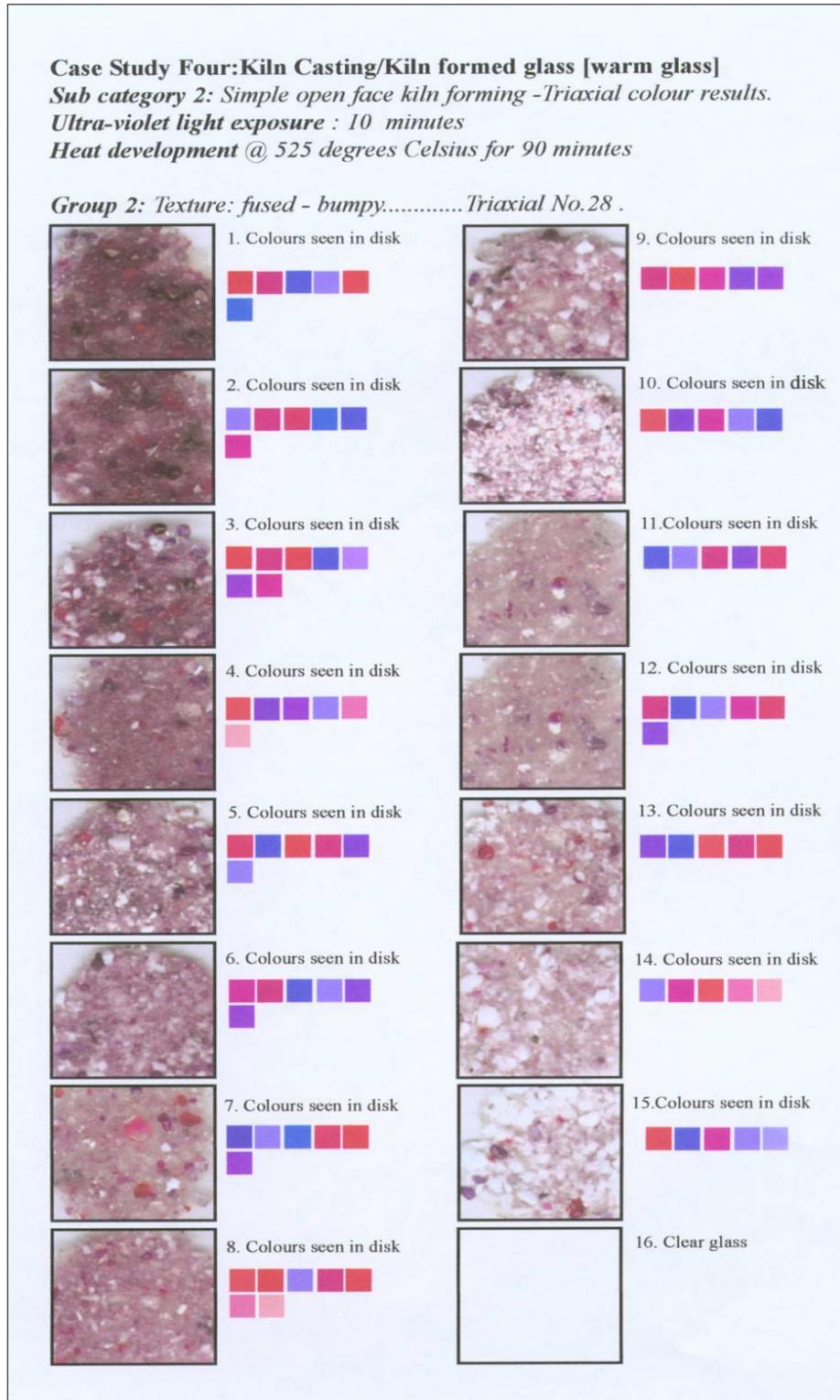
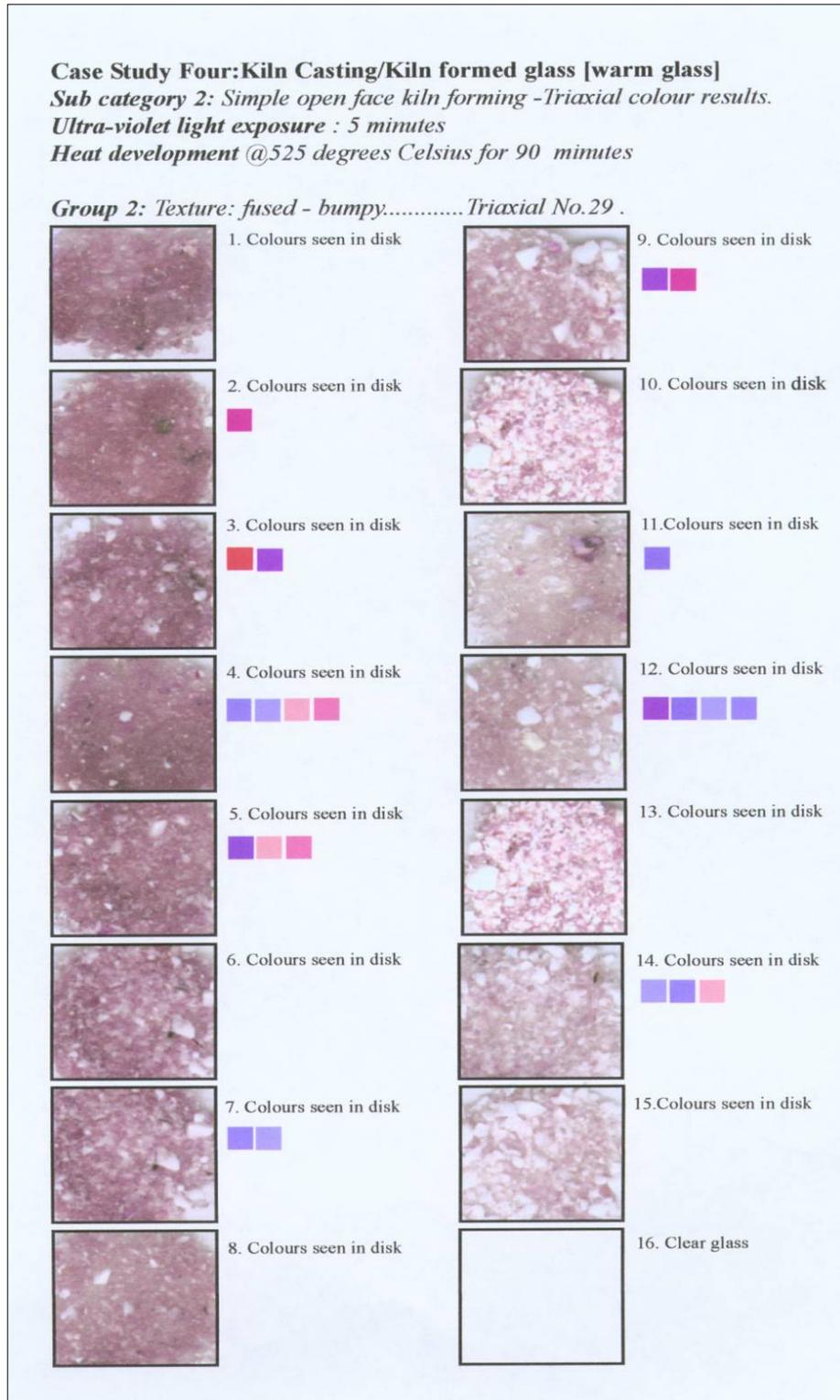


Figure 76c (Triaxial No.28)



**Figure 76e** (Triaxial No.29)



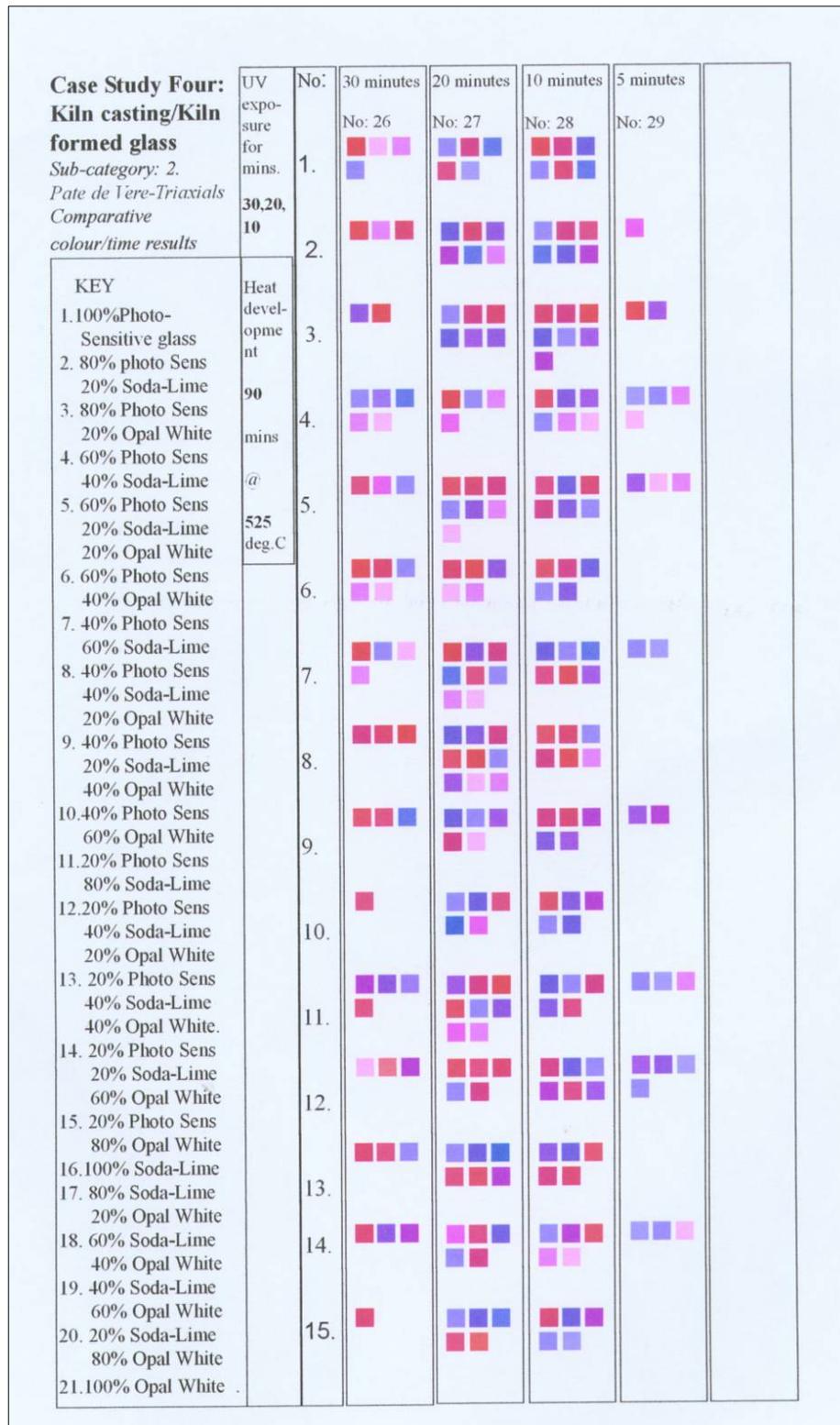
**Figure 76d** (Comparative timed UV exposure results)

Case Study Four: Kiln Formed Photosensitive glass		Temp degrees Celsius	No:	Ultra violet light exposure times.			
				5 mins	10 mins	20 mins	30 mins
<b>Sub-category 1:</b> <i>Pate de Vere                      Triaxials                      Comparative UV                      Exposure Results</i>		525	1.				
			2.				
			3.				
			4.				
			5.				
		90	6.				
			7.				
			8.				
			9.				
			10.				
			11.				
			12.				
			13.				
			14.				
			15.				

KEY	
1.	100% Photo-Sensitive glass
2.	80% photo Sens 20% Soda-Lime
3.	80% Photo Sens 20% Opal White
4.	60% Photo Sens 40% Soda-Lime
5.	60% Photo Sens 20% Soda-Lime 20% Opal White
6.	60% Photo Sens 40% Opal White
7.	40% Photo Sens 60% Soda-Lime
8.	40% Photo Sens 40% Soda-Lime 20% Opal White
9.	40% Photo Sens 20% Soda-Lime 40% Opal White
10.	40% Photo Sens 60% Opal White
11.	20% Photo Sens 80% Soda-Lime
12.	20% Photo Sens 40% Soda-Lime 20% Opal White
13.	20% Photo Sens 40% Soda-Lime 40% Opal White
14.	20% Photo Sens 20% Soda-Lime 60% Opal White
15.	20% Photo Sens 80% Opal White
16.	100% Soda-Lime
17.	80% Soda-Lime 20% Opal White
18.	60% Soda-Lime 40% Opal White
19.	40% Soda-Lime 60% Opal White
20.	20% Soda-Lime 80% Opal White
21.	100% Opal White

**Figure 76f** (Comparative colour/time results)



## Analysis Figure 76

Section J at 525 degrees Celsius for 90 minutes developing time.

- **UV exposure:**
- **5 minutes: No. 29** shows the colours starting to develop at a very early stage. Mauve, pink-violet and dark pinks can be seen in 9 disks. These colours were pale and just beginning to emerge in the disks.
- **10 minutes No. 28** I observed that a wider range of colours. Mainly purple, violet, mauve, blue, red pinks and some orange can be seen.
- **20 minutes No. 27:** A good development. Shows a heaving scattering of mauve, and violet, and a good number of purple and blue, three oranges amongst the reds, wine-reds, cherises, pink reds, and a variety of pinks for 90 minutes.
- **30 minutes No. 26** Shows a low to moderate colour development range of some mauve, some violet and few blues amongst the reds, pink-reds oranges-reds, wine-reds and assorted pinks.
- **Conclusion:** Good strong colour development at 10 minutes and 20 minutes. A Good potential at the heat development temperature of 525 degrees Celsius for the shorter time of 90 minutes.

**Figure 77**

**Group 2: Section K**

Temperature/Heat development range: @ 525 degrees Celsius

Time taken for colour development 120 minutes

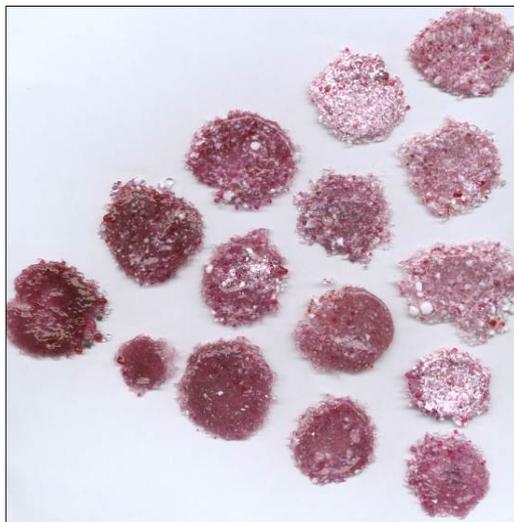
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 25.**  
UV exposure: 5 minutes  
Heat development: @ 525 degrees Celsius  
for 120 minutes.



**Triaxial No: 24.**  
UV exposure: 10 minutes  
Heat development: @ 525 degrees Celsius  
for 120 minutes.

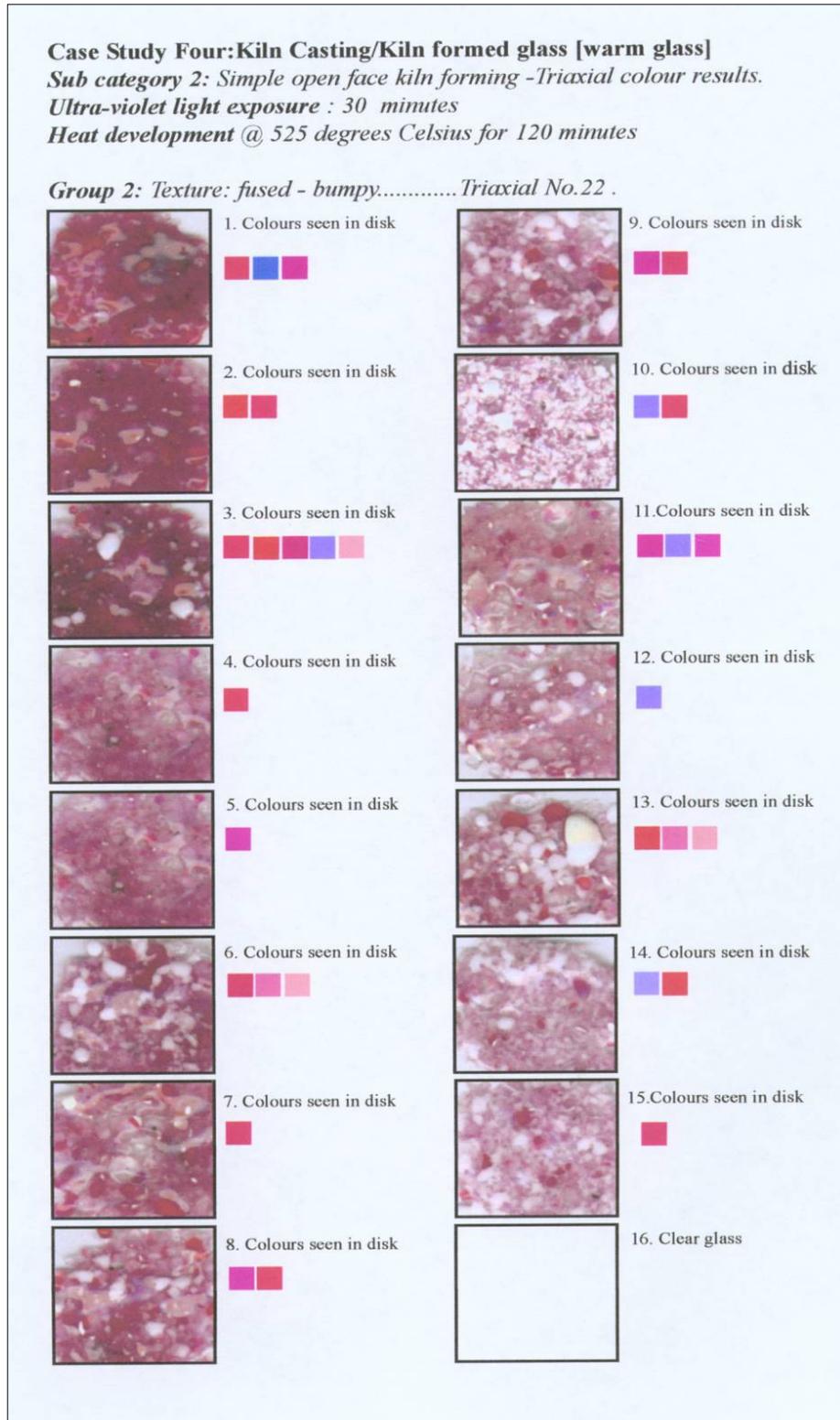


**Triaxial No: 23.**  
UV exposure: 20 minutes  
Heat development: @ 525 degrees Celsius  
for 120 minutes.

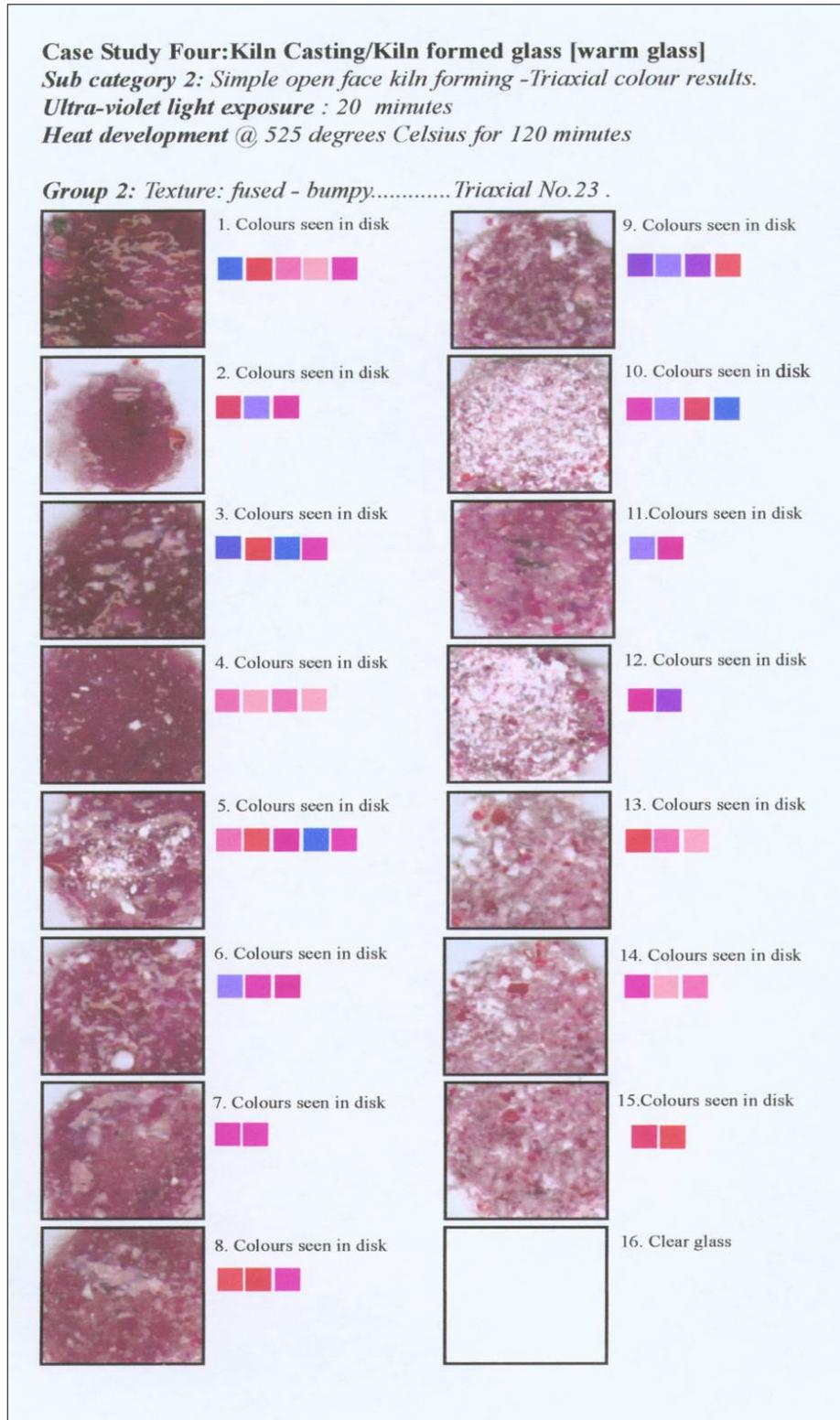


**Triaxial No: 22.**  
UV exposure: 30 minutes  
Heat development: @ 525 degrees Celsius  
for 120 minutes.

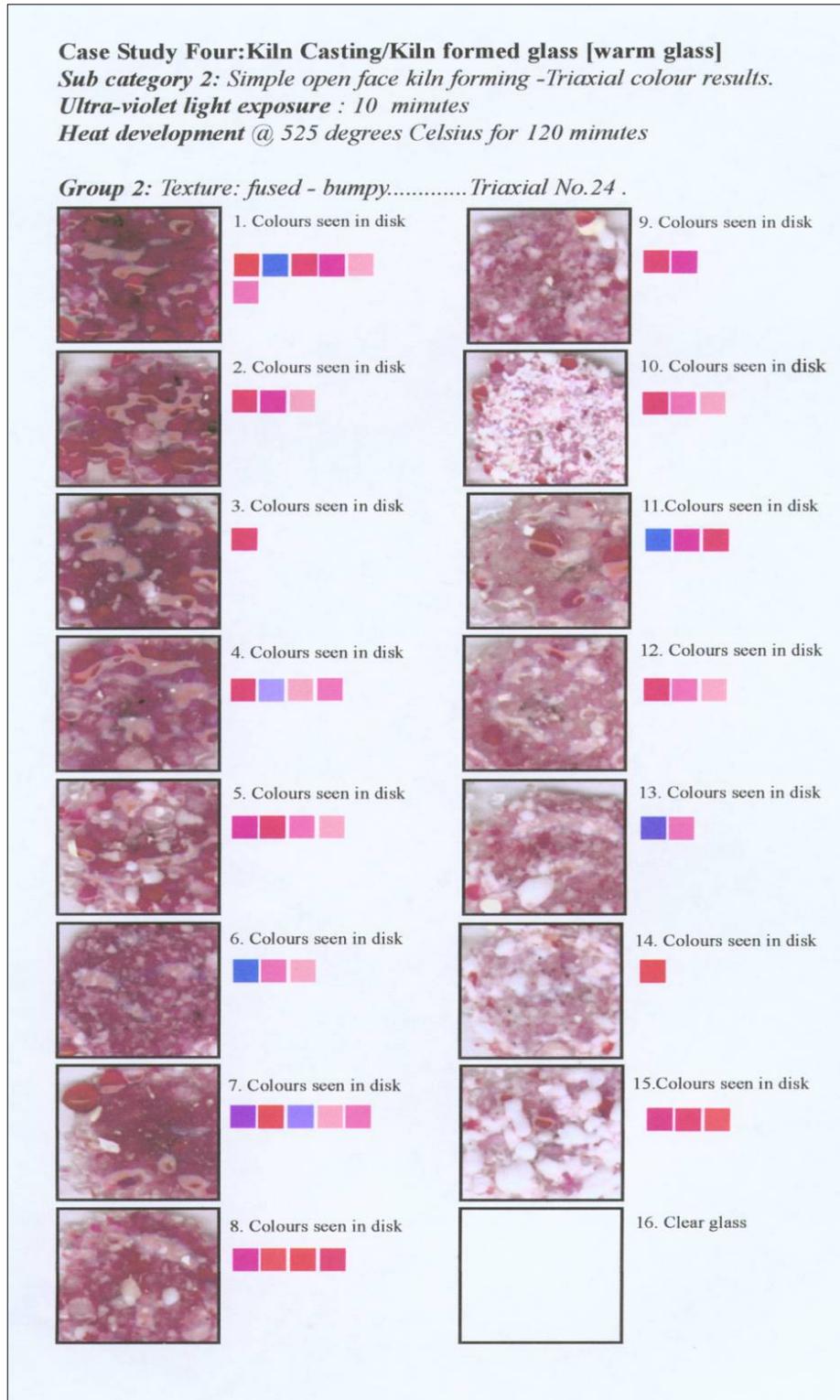
**Figure 77a** (Triaxial No.22)



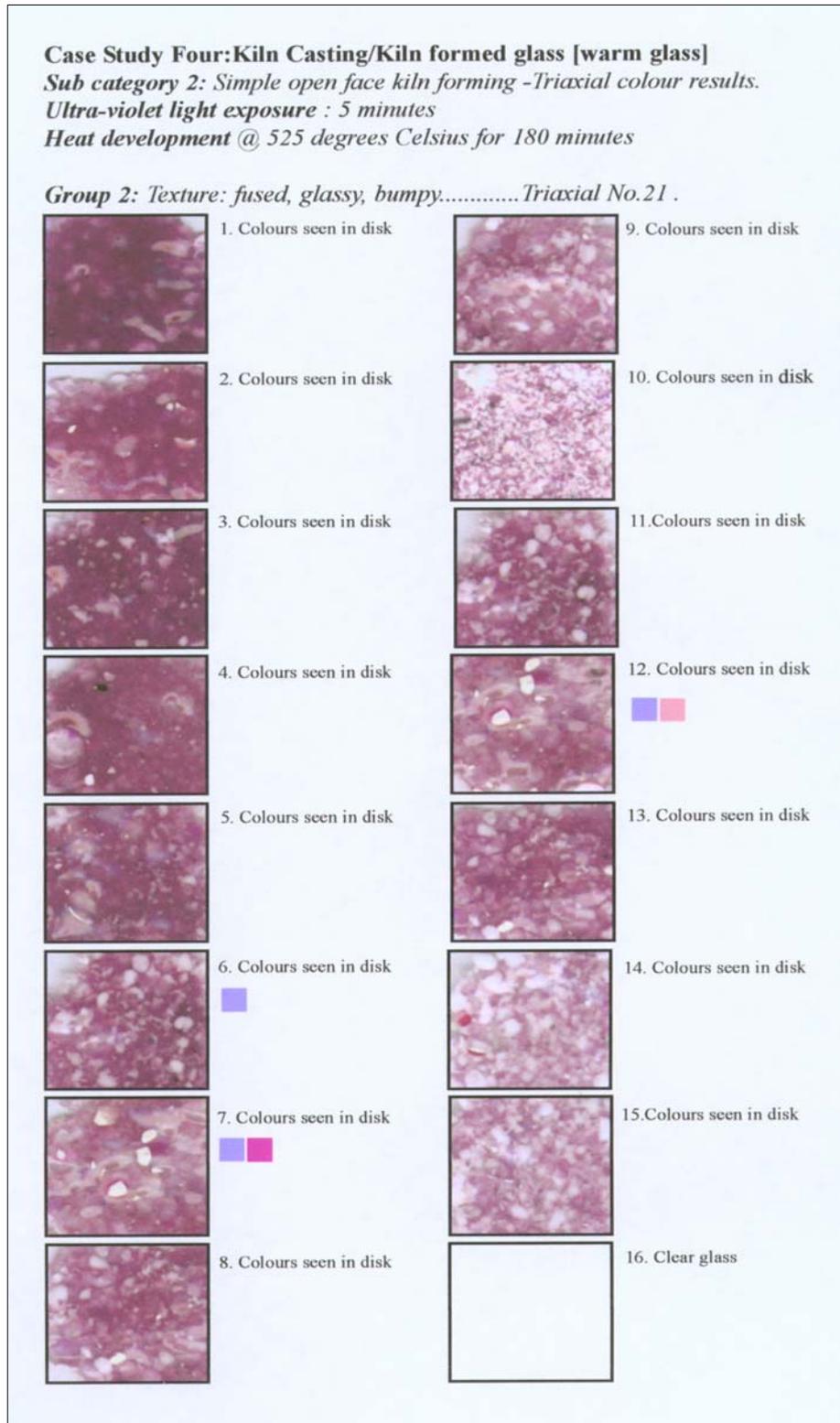
**Figure 77b** (Triaxial No.23)



**Figure 77c (Triaxial No.24)**



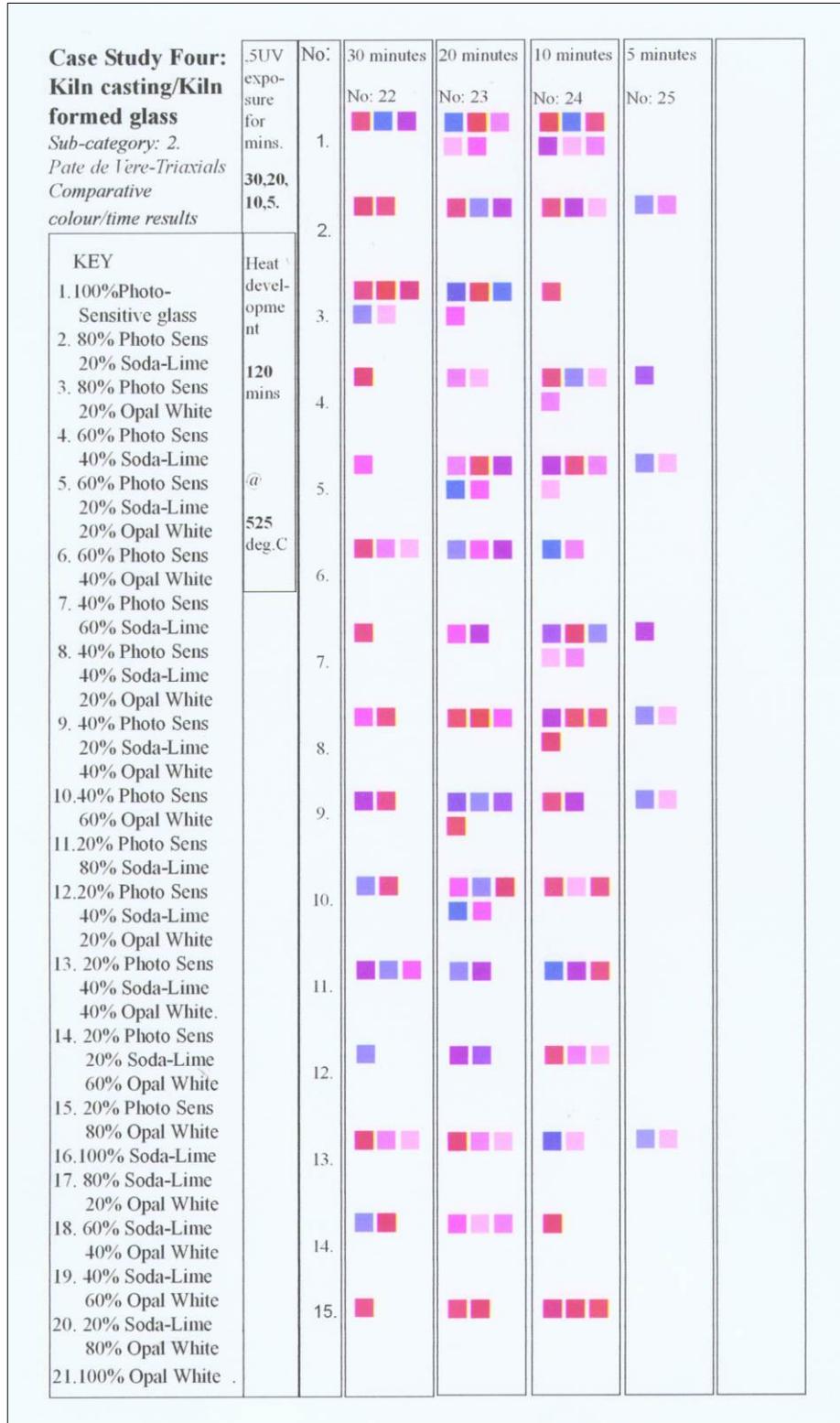
**Figure 77e** (Triaxial No. 25)



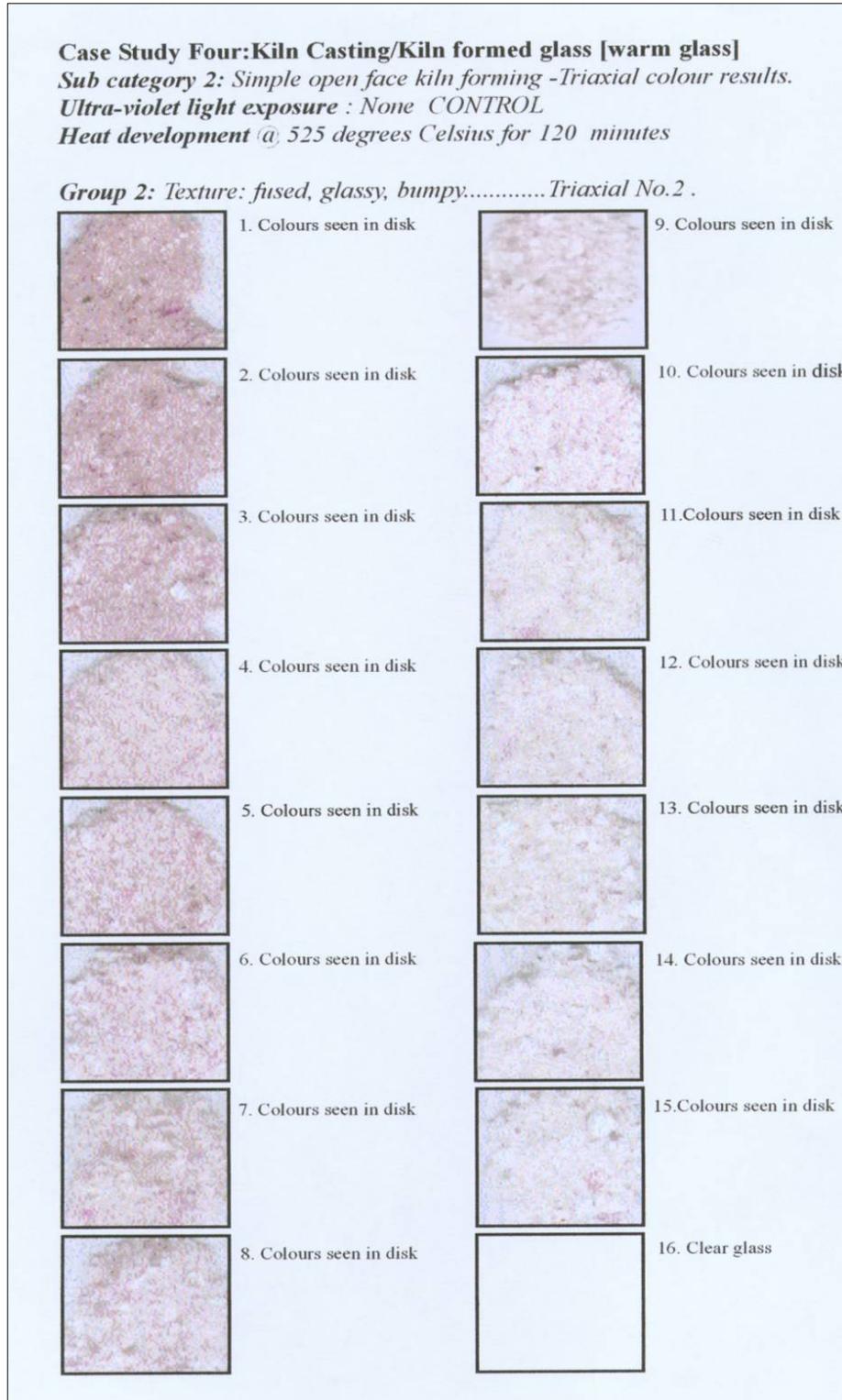
**Figure 77d** (Comparative timed UV exposure results)

<b>Case Study Four: Kiln Formed Photosensitive glass</b>		Temp degrees Celsius	No:	Ultra violet light exposure times.					
				5 mins	10 mins	20 mins	30 mins		
<b>Sub-category 2: Pate de Vere- Triaxials Comparative UV Exposure Results</b>		525	120	1.					
					2.				
					3.				
					4.				
					5.				
					6.				
					7.				
					8.				
					9.				
					10.				
					11.				
					12.				
					13.				
					14.				
					15.				
					16.				
					17.				
					18.				
					19.				
					20.				
					21.				

**Figure 77f** (Comparative colour/time results)



**Figure 77g CONTROL @ 525 degrees Celsius for 120 minutes. (Triaxial No. 2)**



## Analysis Figure 77

Section K: for 525 degrees Celsius for 120 minutes developing time.

- **UV exposure:**
- **5 minutes No. 25:** Minimal colour development seen. Mainly mauves and pink colours were seen to be at their early development stages as can be seen in disks 2, 4, 5, 7, 8, 9 and 13 and were again very pale in intensity of colour.
- **10 minutes No. 24:** Showed a moderately low development of mainly reds, pinks, a few blues, violet, mauve and one orange.
- **20 minutes No. 23:** Showed a limited development of blue, mauve, one purple, two violets and two oranges amongst the pink-reds, reds, cherises and variety of pinks in seven disks.
- **30 minutes No. 22:** Showed a moderately limited colour range consisting mainly of reds, pink-reds, orange-reds assorted pinks and mainly mauves with good colour intensity.
- **Conclusion:** The UV exposures of 10 and 20 minutes show a limited potential colour development range of at this temperature of 525 degrees Celsius.

**Figure 78**

**Group 3: Section L**

Temperature/Heat development range: @ 525 degrees Celsius

Time taken for colour development 180 minutes

Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



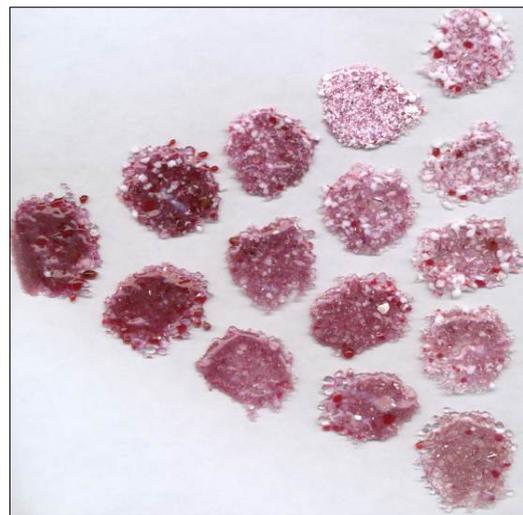
**Triaxial No: 21.**  
UV exposure: 5 minutes  
Heat development: @ 525 degrees Celsius  
for 180 minutes.



**Triaxial No: 20.**  
UV exposure: 10 minutes  
Heat development: @ 525 degrees Celsius  
for 180 minutes.

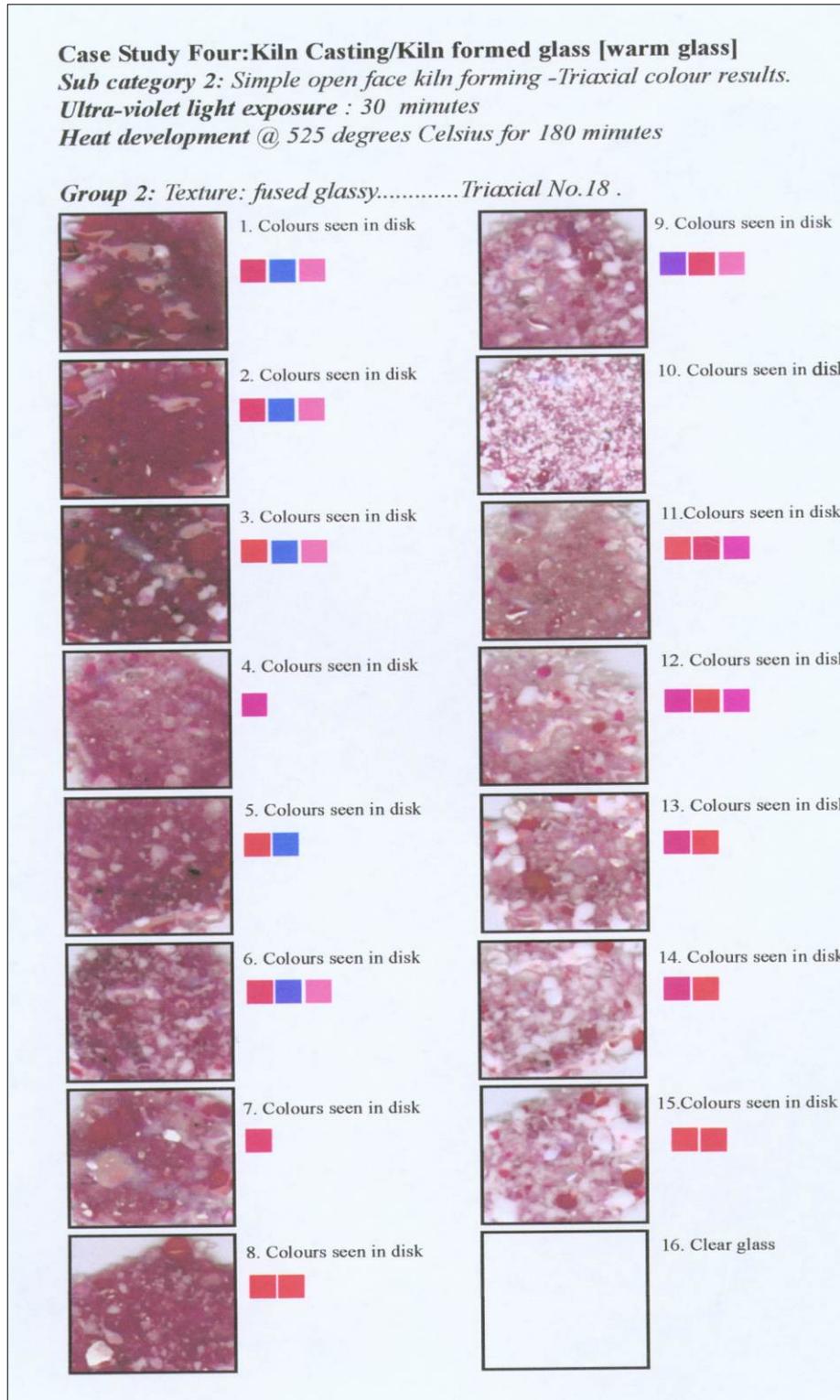


**Triaxial No: 19.**  
UV exposure: 20 minutes  
Heat development: @ 525 degrees Celsius  
for 180 minutes.



**Triaxial No: 18.**  
UV exposure: 30 minutes  
Heat development: @ 525 degrees Celsius  
for 180 minutes.

**Figure 78a** (Triaxial No.18)



**Figure 78b** (Triaxial No. 19)

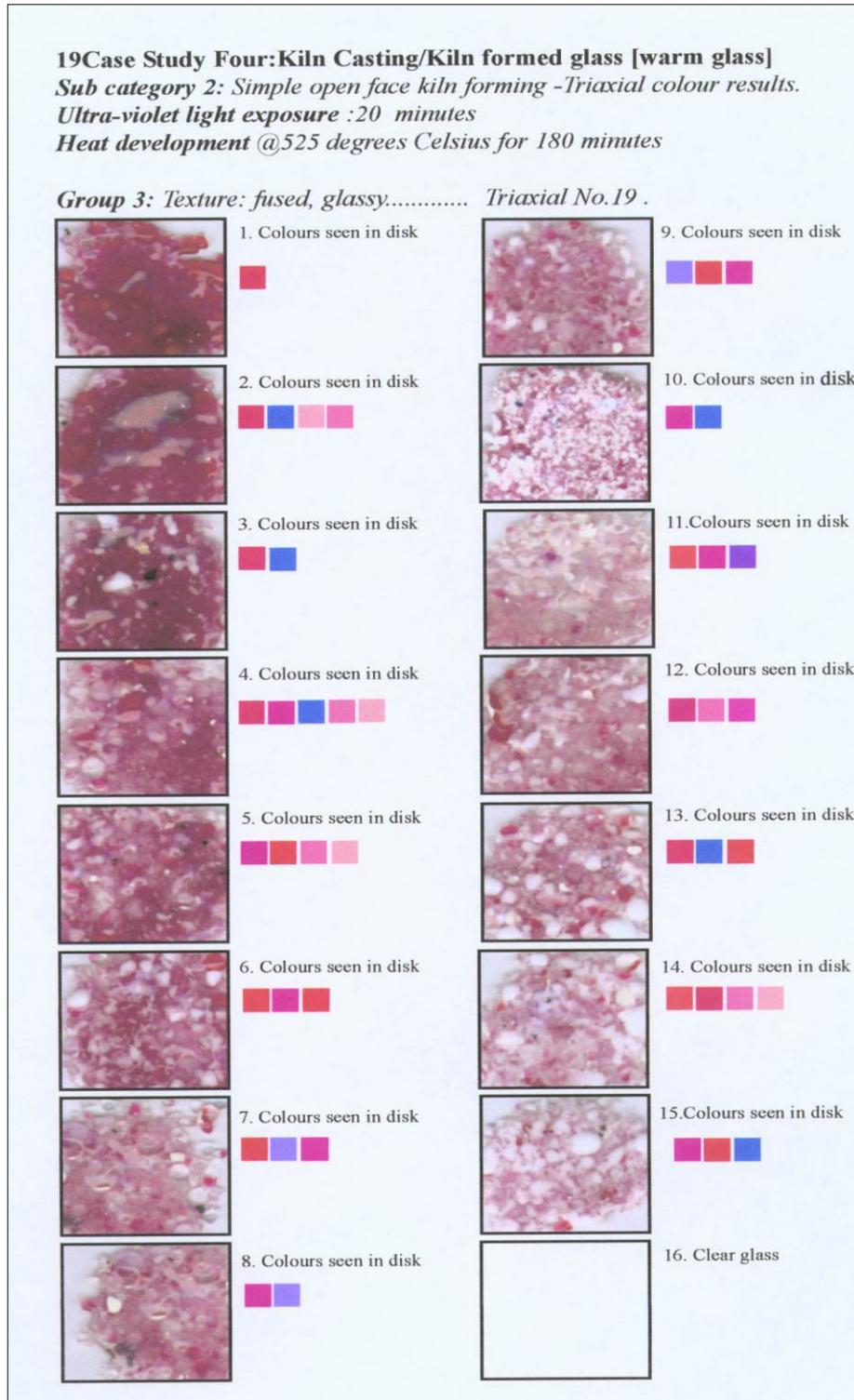
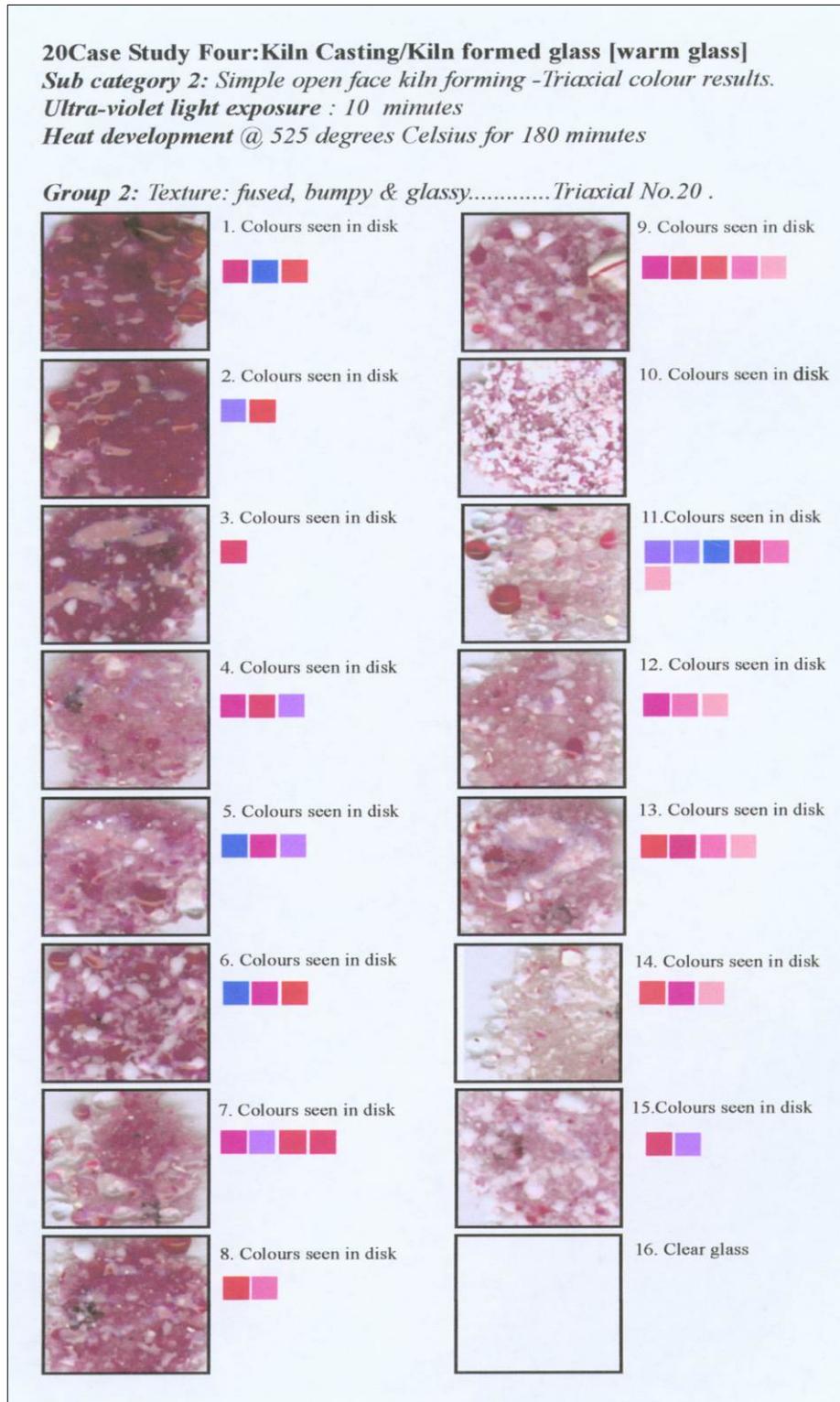
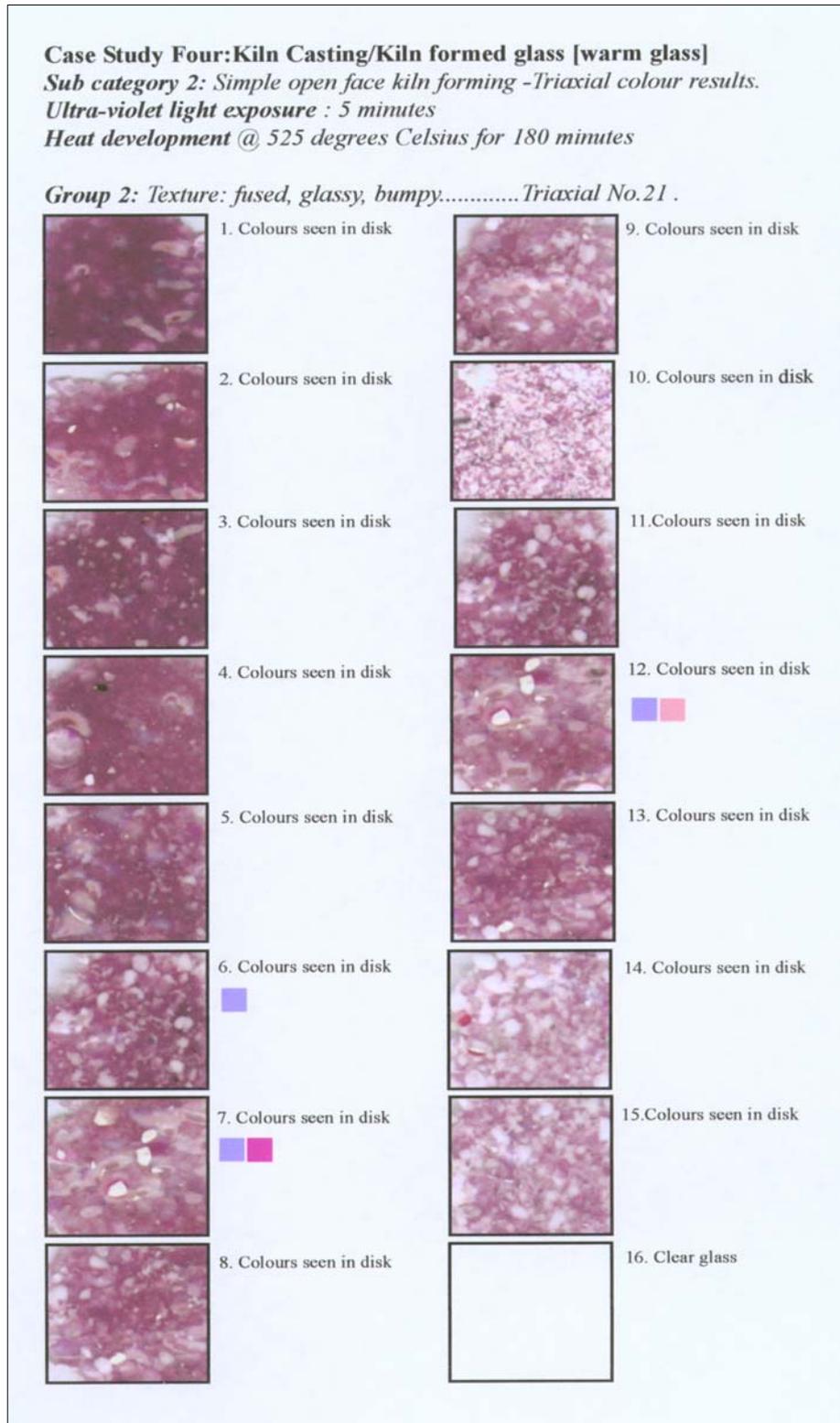


Figure 78c (Triaxial No. 20)



**Figure 78e** (Triaxial No. 21)



**Figure 78d** (Comparative timed UV results)

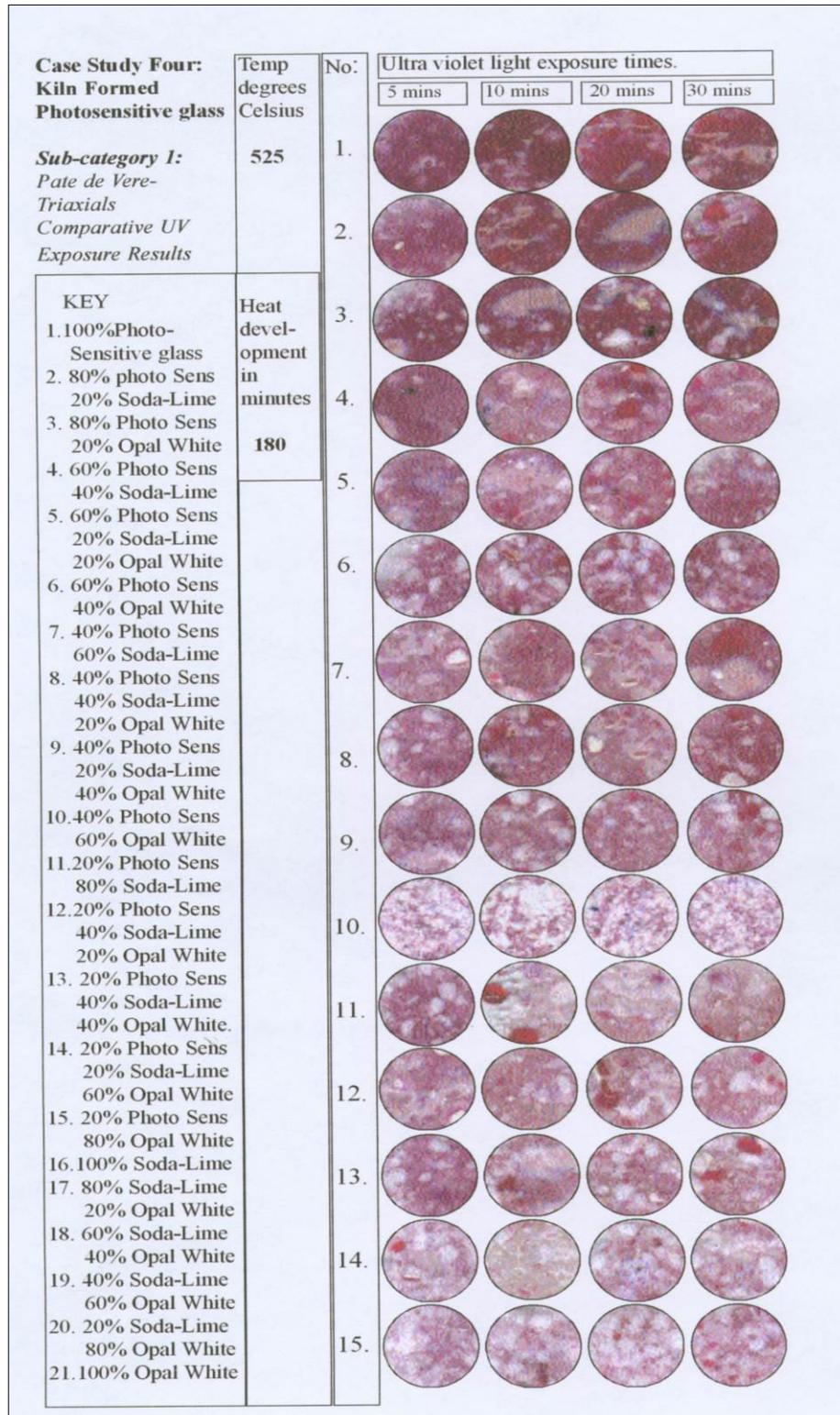
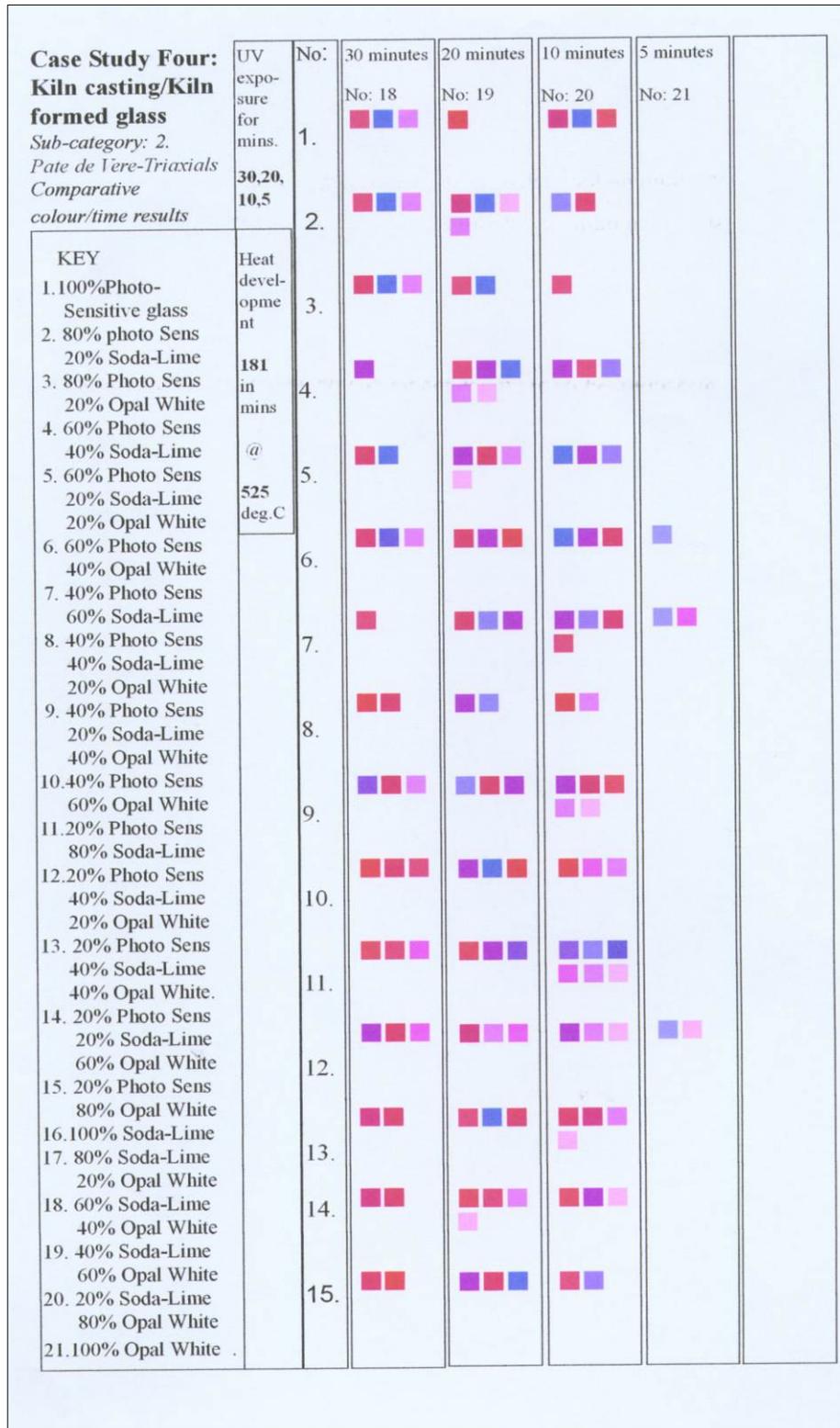


Figure 78f (Comparative colour/time results)



### **Analysis of Figure 78**

Section L: for 525 degrees Celsius for 180 minutes developing time.

- **UV exposure:**
- **5 minutes No. 21:** Shows a very limited development of five colours starting to develop in disks No 6, 7 and 12. These few colours of mauves, and pinks were very immature.
- **10 minutes No.20:** Shows a low to moderate development of a range of colours such as reds, pinks, orange-pinks, mauves and some blues that are paler than in other developments.
- **20 minutes No.19:** Shows a moderate to low development of mainly reds, pinks, pink-reds, pink-oranges, six blues, a few mauves, and a violet for 180 minutes
- **30 minutes No.18:** Shows a moderate to low development of 4 blues amongst the reds- orange reds red-pinks, cerise and orange.
- **Conclusion:** A moderate to low potential for colour development for the temperature and the length of time taken.

**Group 3** was divided into sections according to the length of time it took to develop the colours at the ultraviolet light exposure times of 5 minutes, 10 minutes, 20 minutes and 30 minutes at the heat development times of 90, 120, and 180 minutes. Control triaxial No.1. UV exposure: None. Heat development @ 550 degrees Celsius for 120 minutes. Triaxial No. 17 was an experiment with a high temperature of 550 degrees Celsius and long heat development of 240 minutes. The general appearance was of muddy haematone colour with a smooth glass surface for each disk. It is not printed in the following section as it was mislaid.

**Figure 79**

**Group 3: Section M**

Temperature/Heat development range: @ 550 degrees Celsius

Time taken for colour development 90 minutes

Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



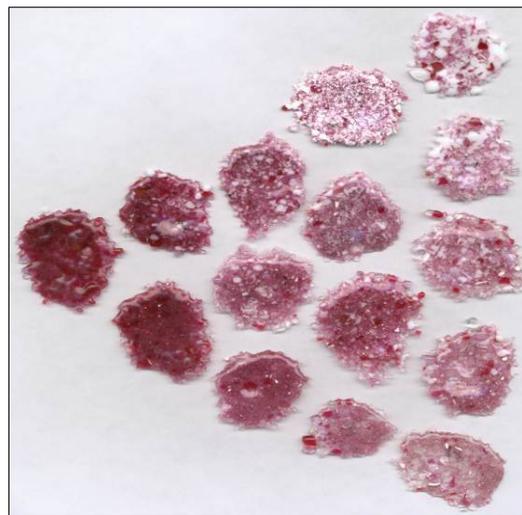
**Triaxial No: 15.**  
UV exposure: 5 minutes  
Heat development: @ 550 degrees Celsius  
for 90 minutes.



**Triaxial No: 14.**  
UV exposure: 10 minutes  
Heat development: @ 550 degrees Celsius  
for 90 minutes.

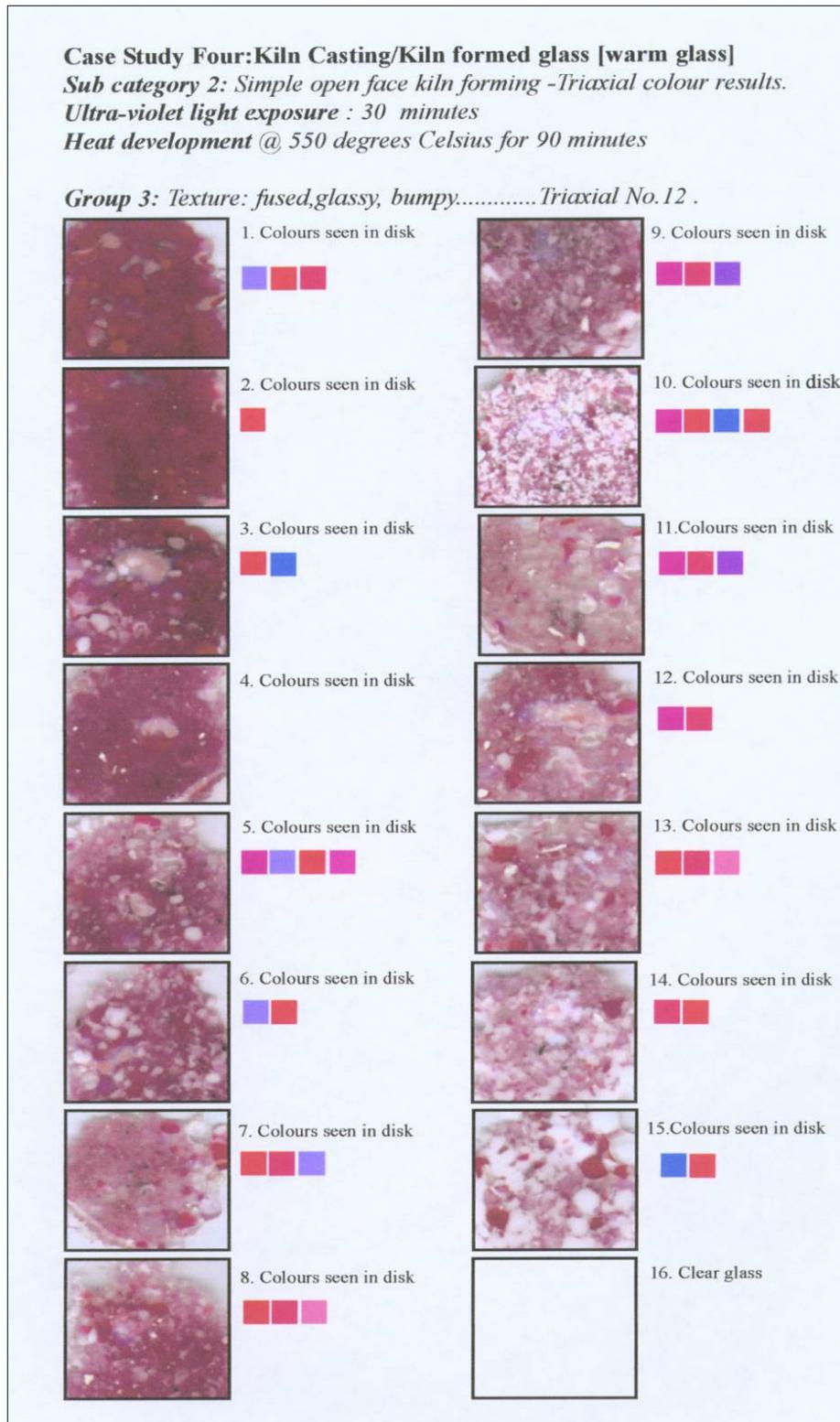


**Triaxial No: 13.**  
UV exposure: 20 minutes  
Heat development: @ 550 degrees Celsius  
for 90 minutes.

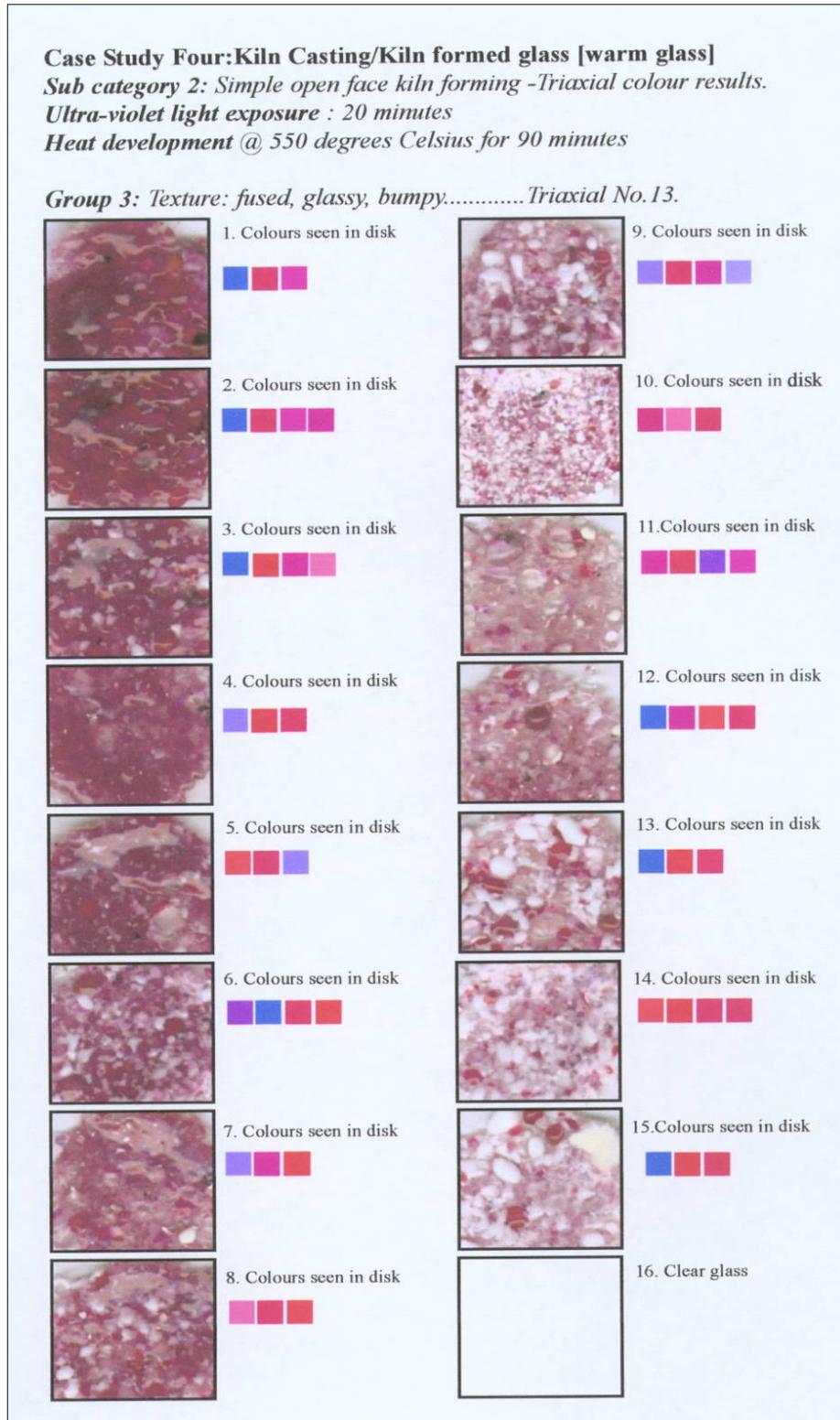


**Triaxial No: 12.**  
UV exposure: 30 minutes  
Heat development: @ 550 degrees Celsius  
for 90 minutes.

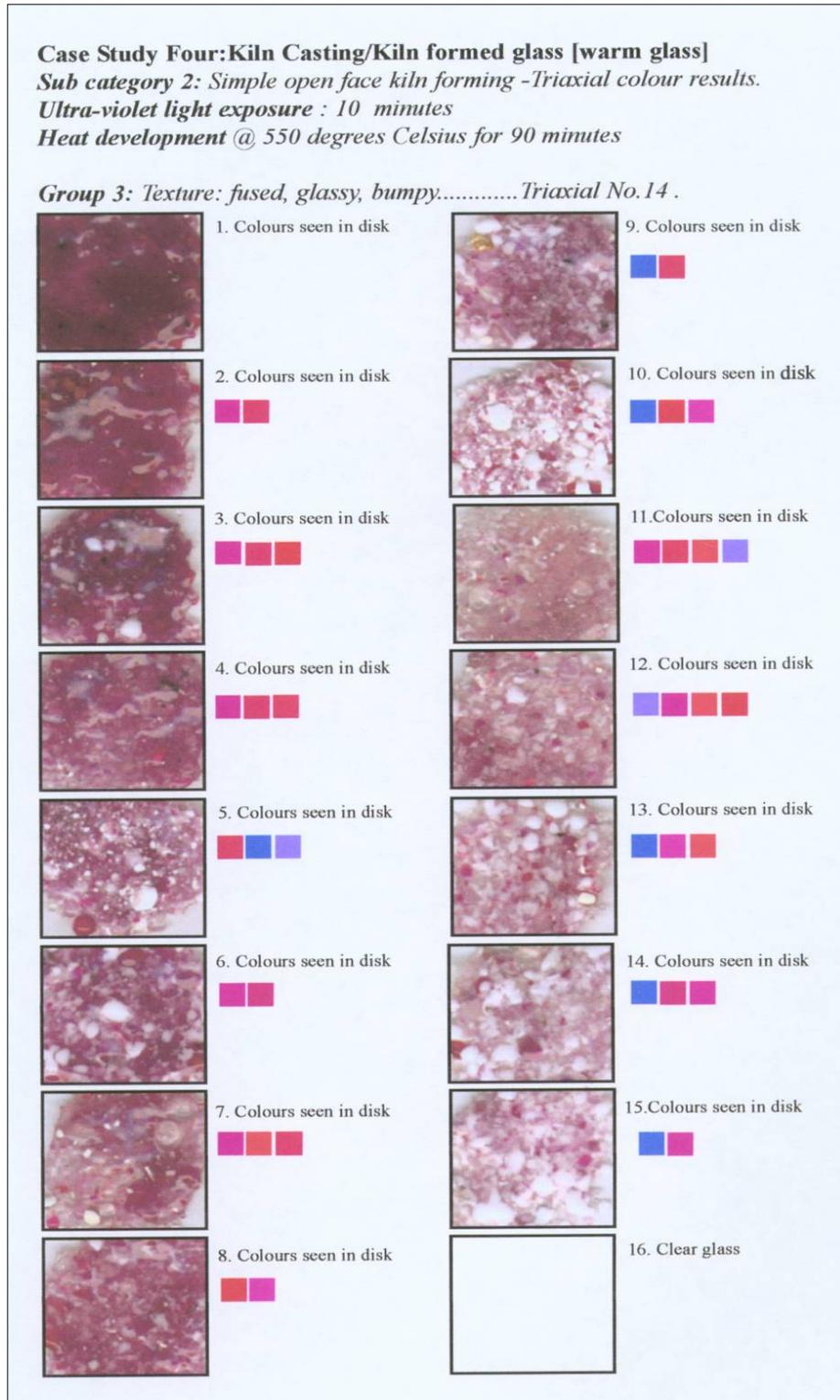
**Figure 79a** (Triaxial No.12)



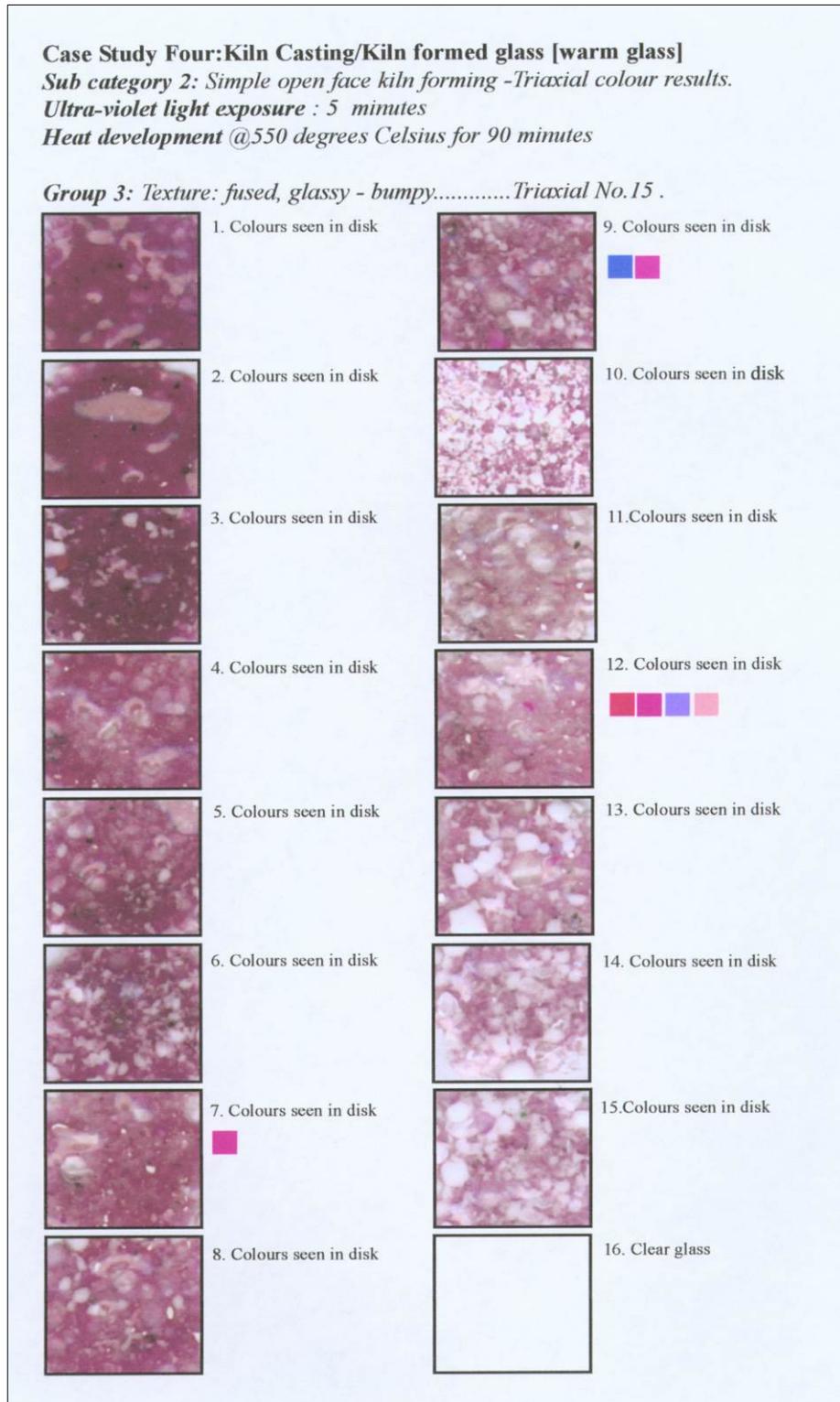
**Figure 79b** (Triaxial No.13)



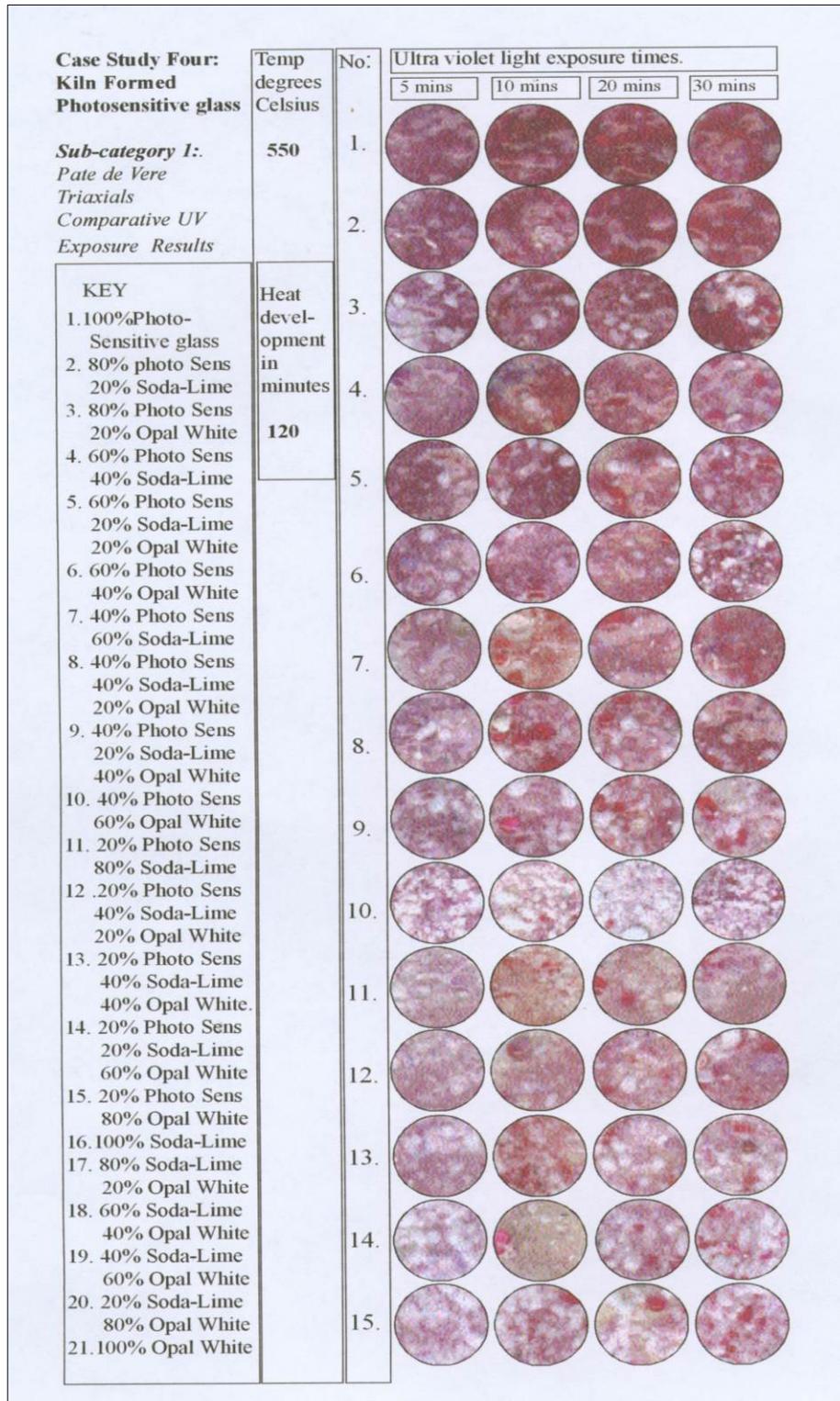
**Figure 79c (Triaxial No.14)**



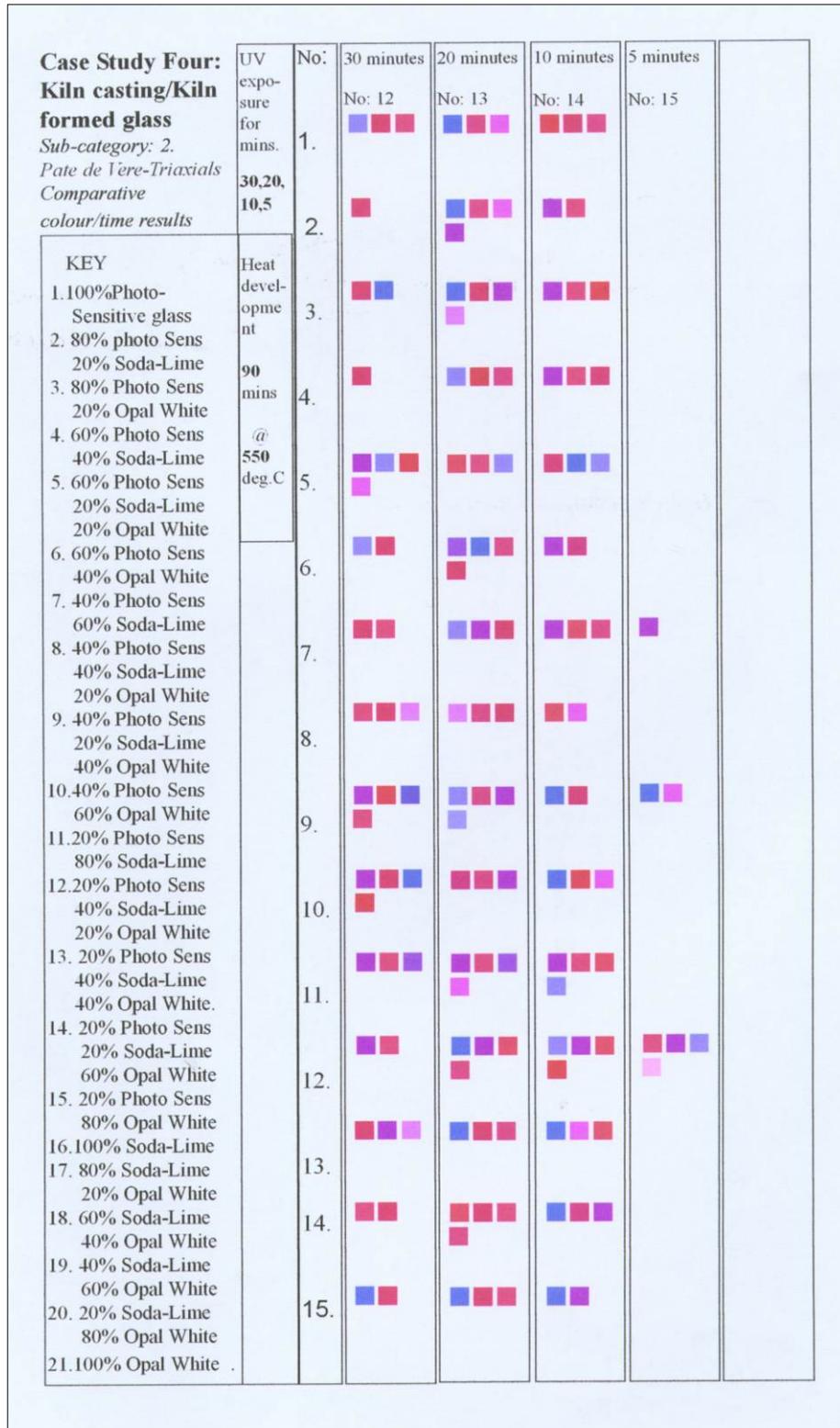
**Figure 79e (Triaxial No.15)**



**Figure 79d** (Comparative timed UV exposure results)



**Figure 79f** (Comparative colour/time results)



### **Analysis of Figure 79**

Section M: for 550 degrees Celsius for 90 minutes developing time.

- **UV exposure:**
- **5 minutes No. 15:** A very limited development. Only three disks showed a colour development. All six colours were strong vibrant colours.
- **10 minutes No. 14:** A moderately limited colour development was seen in all the disks. The variety of colours was limited to 6 blue, 4 orange, 3 mauve, 10 cerise amongst a variety of red, pink-reds, orange-reds and orange-pinks.
- **20 minutes No. 13:** A low to moderate colour development, all the disk have at least 3 colours present... 7 blue, 5 mauve, 3 orange, 1 purple and 1 violet seen amongst the pink-reds, cerise, orange-pinks, orange-reds and variety of pinks.:
- **30 minutes No. 12:** A moderately low colour development in all the disks. 1 blue, 1 purple, 1 violet, 4 mauve, and 1 orange seen amongst a sparse number of reds, orange-pinks, orange-reds and a variety of pinks.
- **Conclusion:** A limited to low potential for colour development in UV exposed triaxials for 10, 20 and 30 minutes for the short time of 90 minutes.

**Figure 80**

**Group 3: Section N**

Temperature/Heat development range: @ 550 degrees Celsius

Time taken for colour development 120 minutes

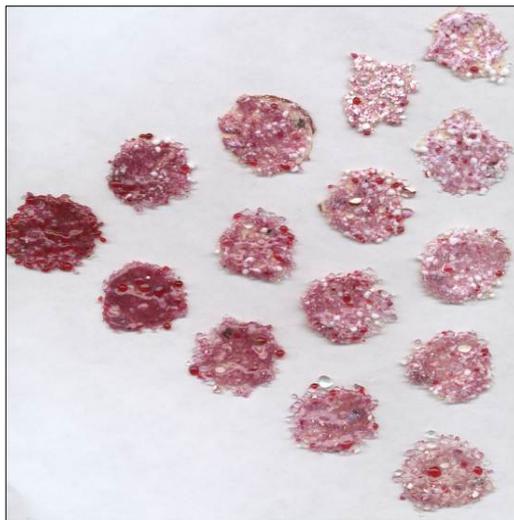
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 11.**  
UV exposure: 5 minutes  
Heat development: @ 550 degrees Celsius  
for 120 minutes.



**Triaxial No: 10.**  
UV exposure: 10 minutes  
Heat development: @ 550 degrees Celsius  
for 120 minutes.

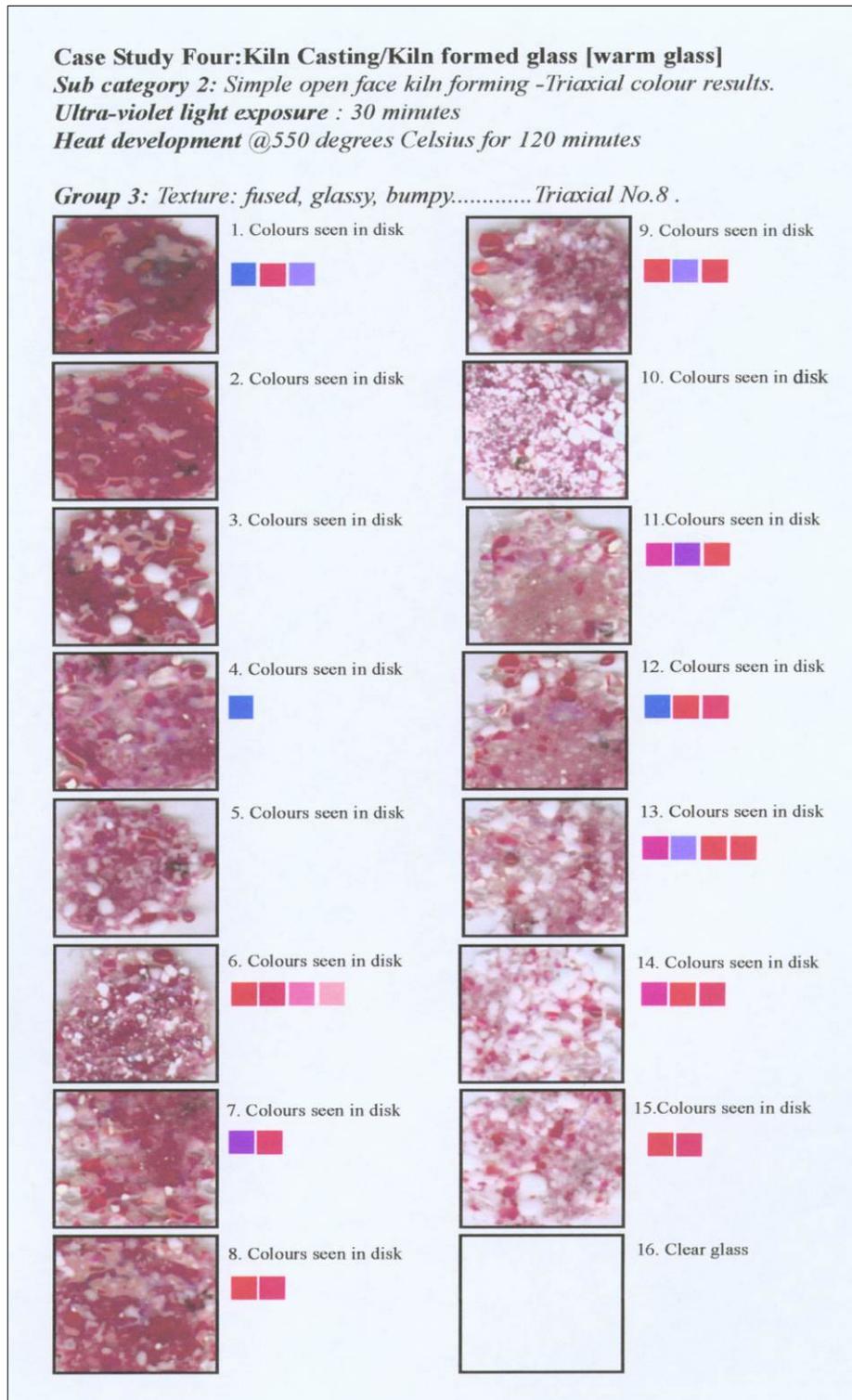


**Triaxial No: 9.**  
UV exposure: 20 minutes  
Heat development: @ 550 degrees Celsius  
for 120 minutes.

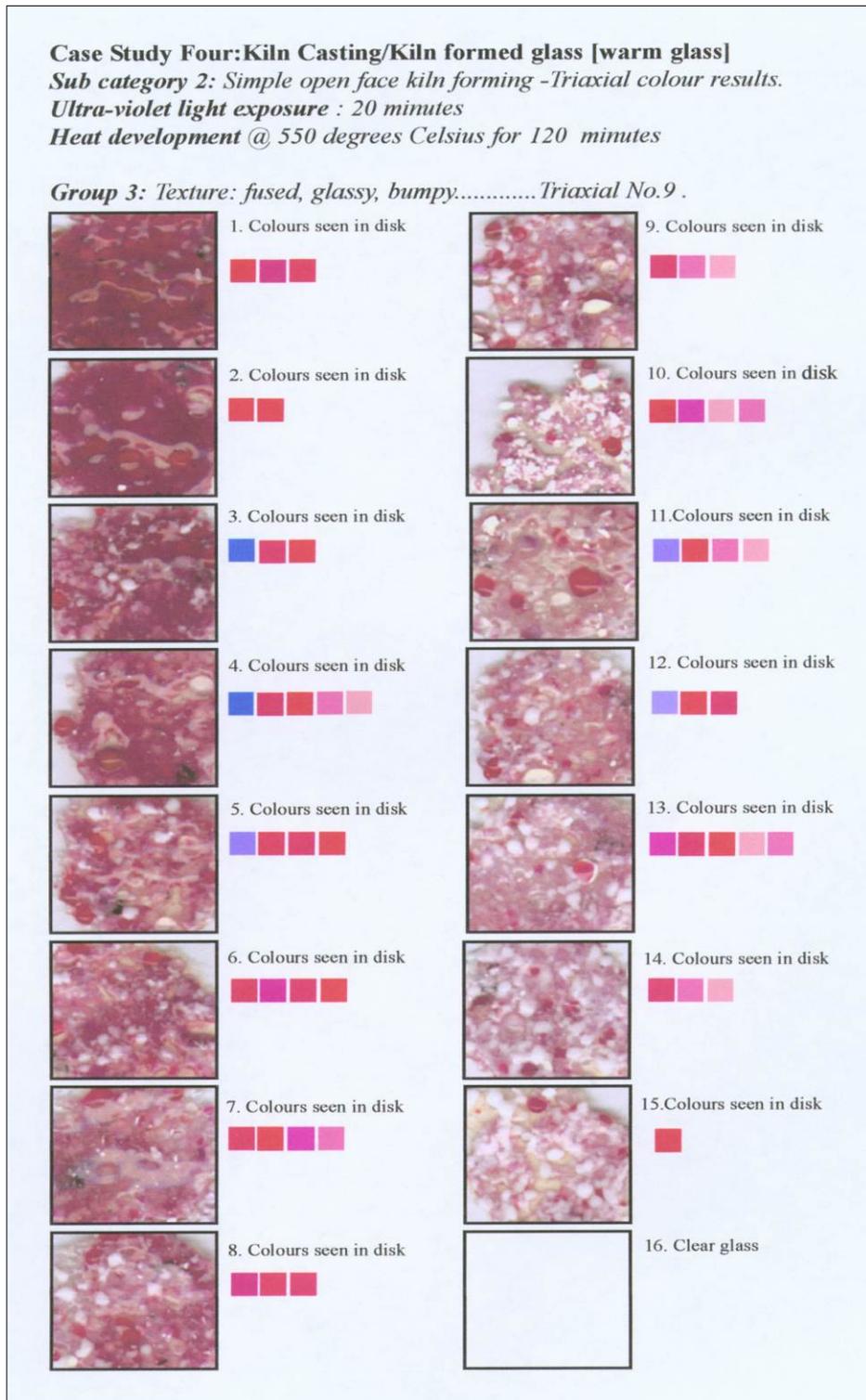


**Triaxial No: 8.**  
UV exposure: 30 minutes  
Heat development: @ 550 degrees Celsius  
for 120 minutes.

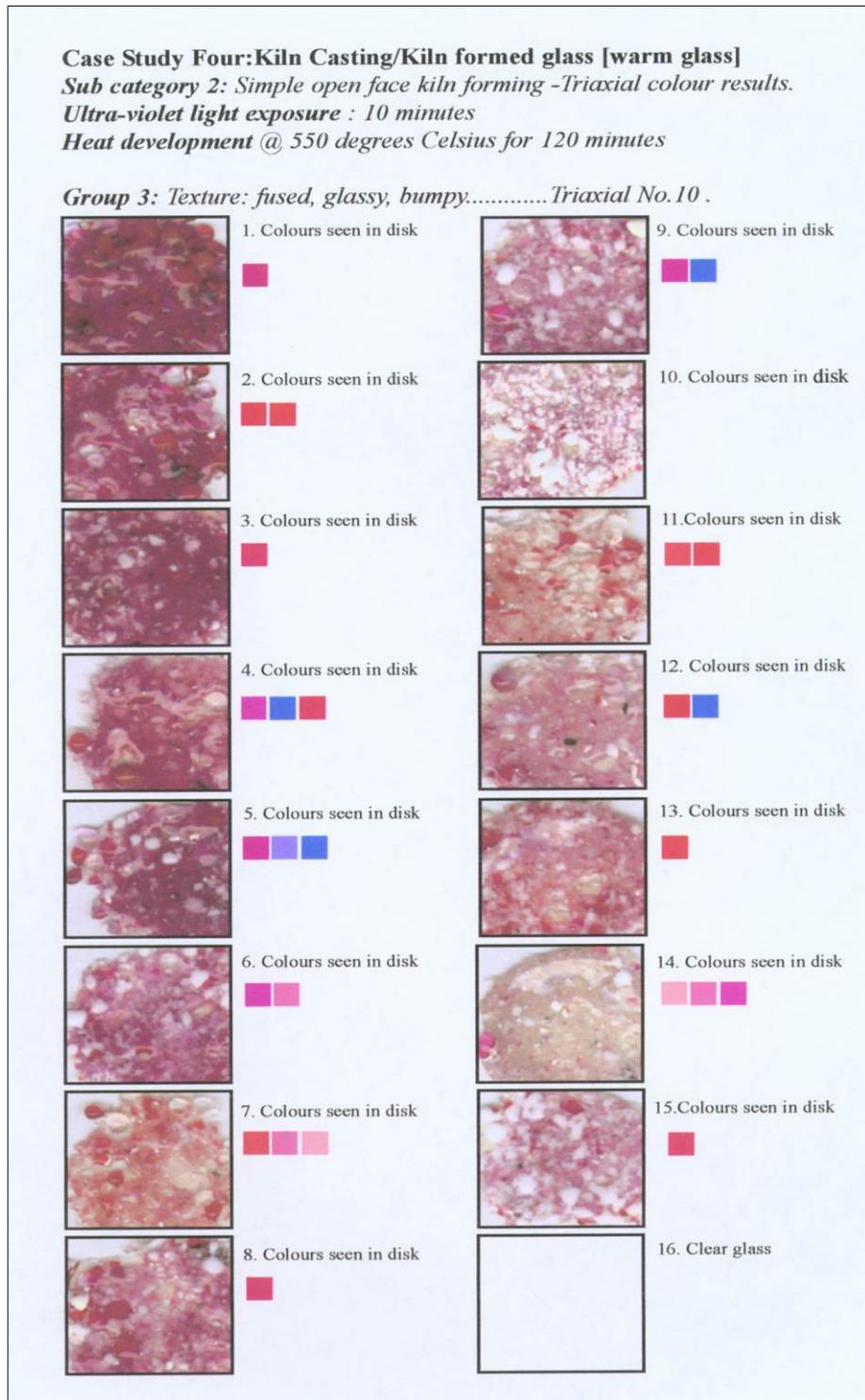
**Figure 80a** (Triaxial No.8)



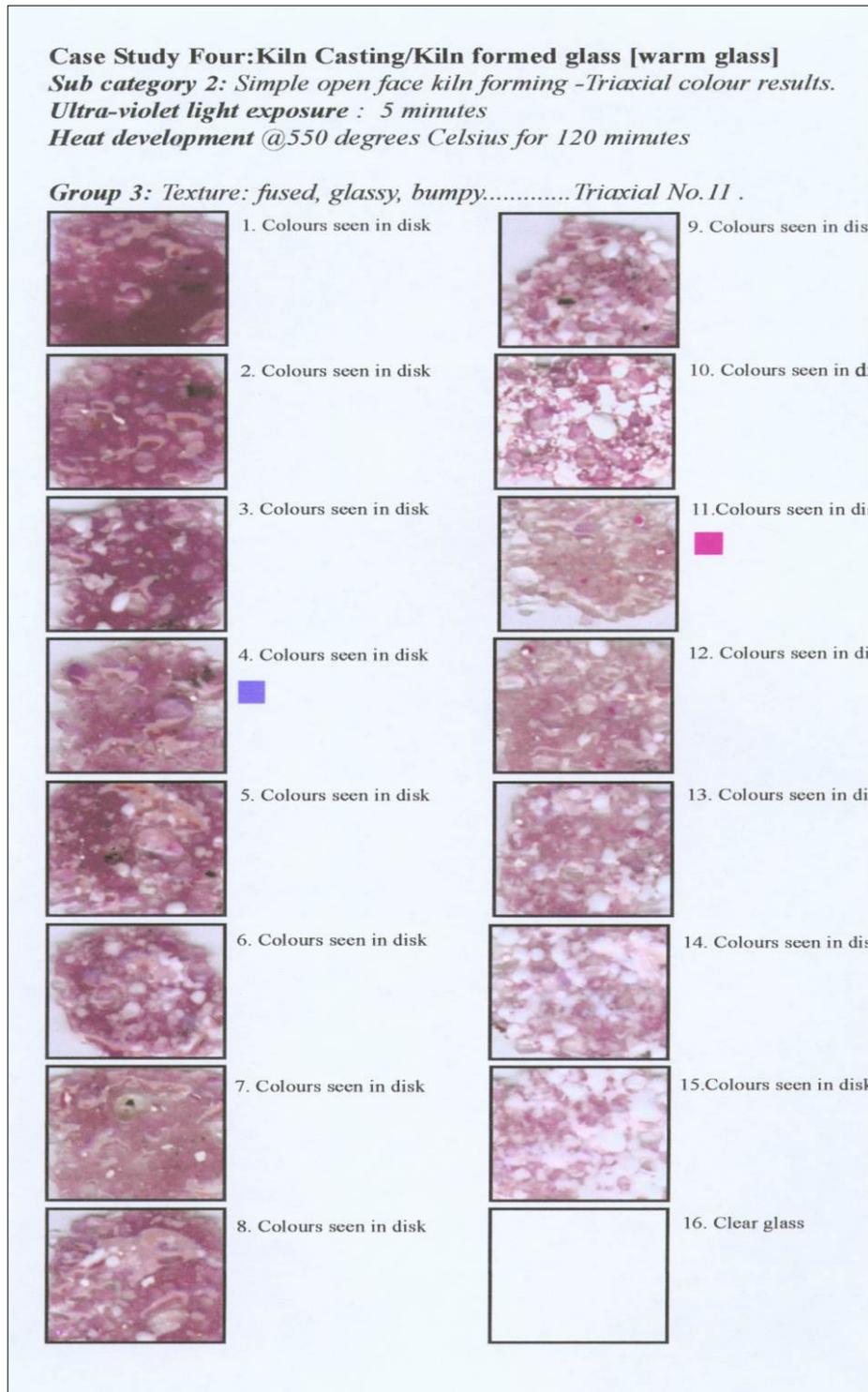
**Figure 80b** (Triaxial No.9)



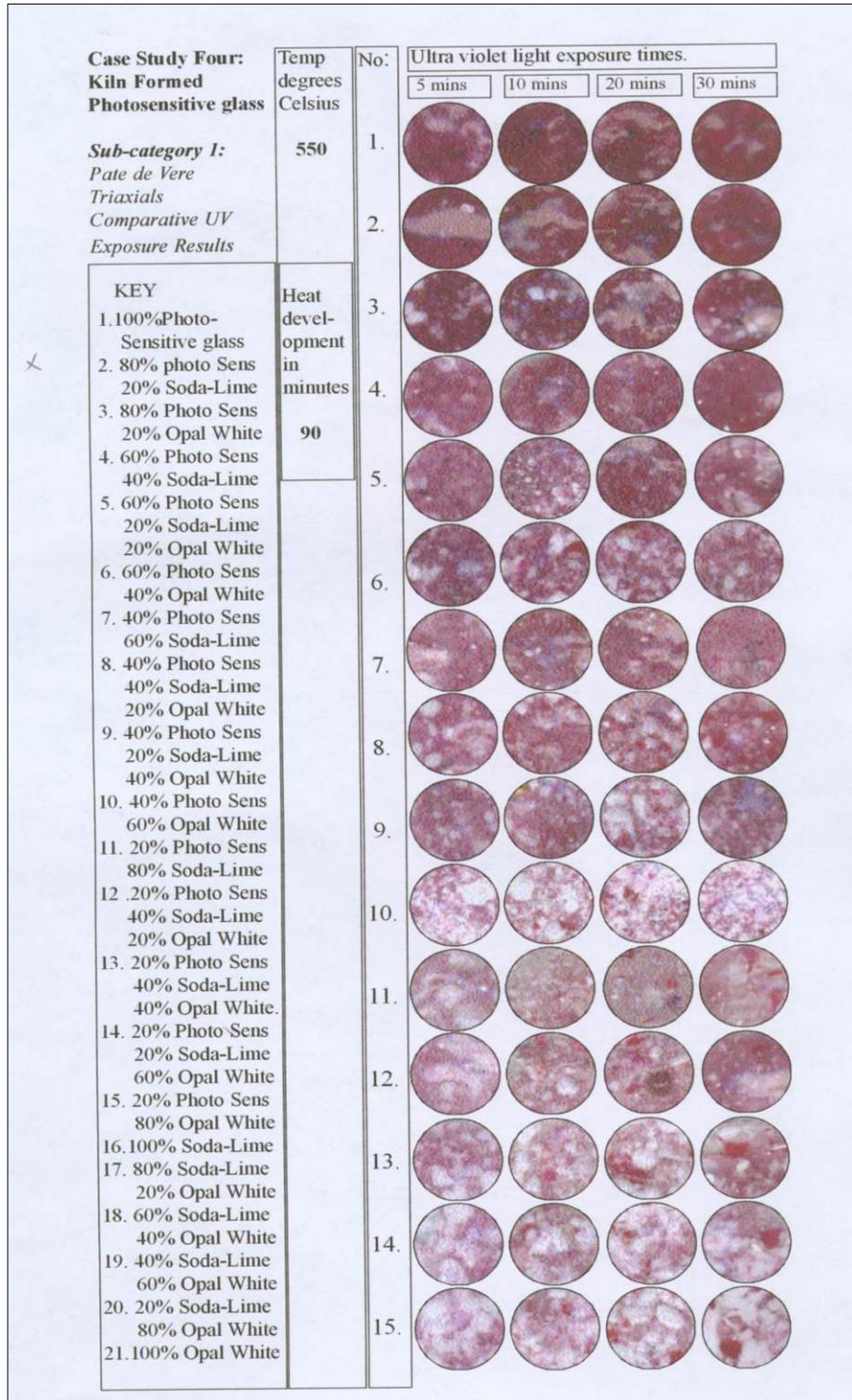
**Figure 80c** (Triaxial No.10)



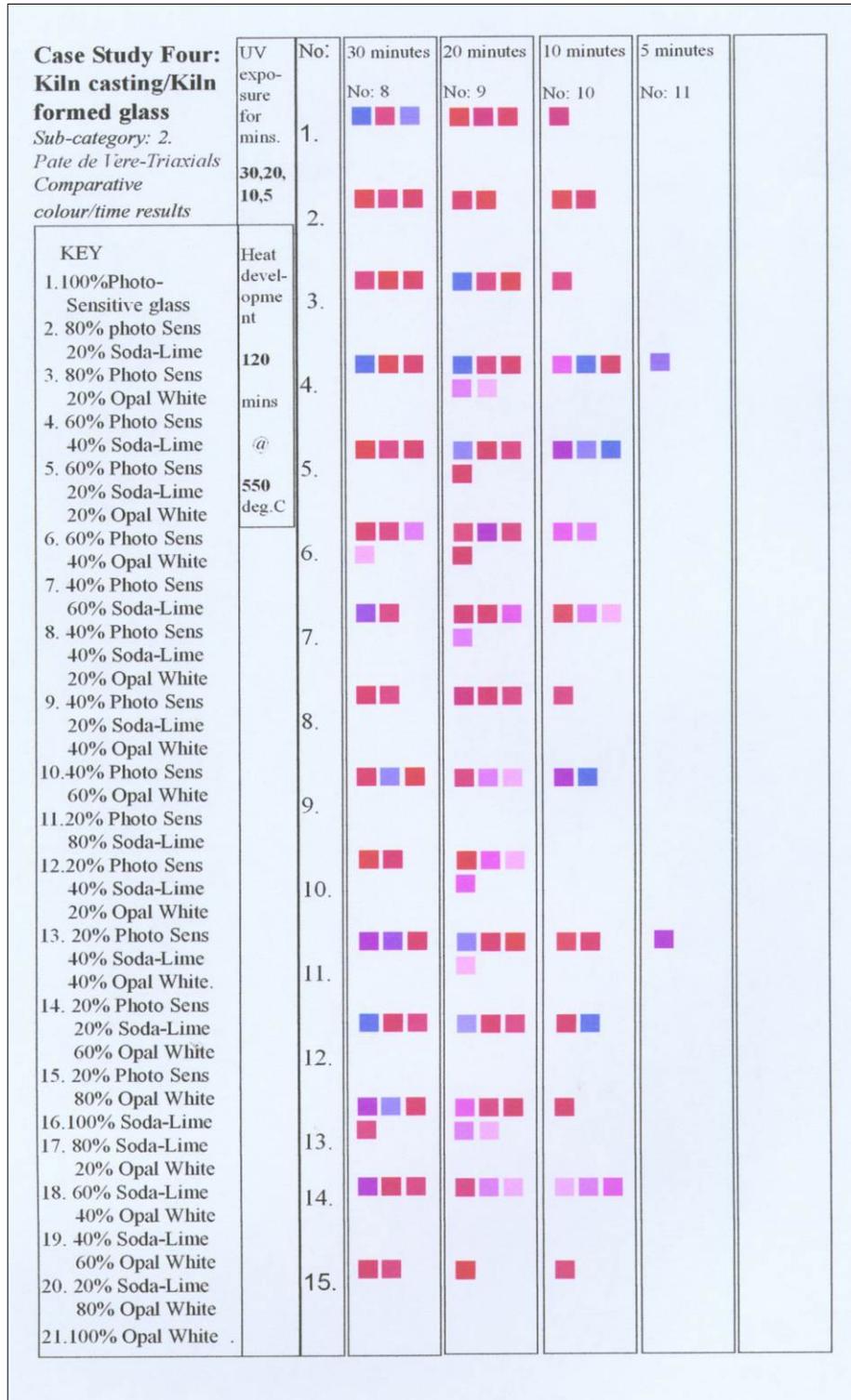
**Figure 80e** (Triaxial No.11)



**Figure 80d** (Comparative timed UV exposure results)



**Figure 80f** (Comparative colour/time results)



### **Analysis for Figure 80**

Section N: for 550 degrees Celsius for 120 minutes developing time.

- **UV exposure:**
- **5 minutes No. 11:** Only two strong colours were seen in disks 4 and 11.
- **10 minutes No.10:** A limited to low development of strong colour in all disks. 4 blue, 1 mauve, 1 orange and a variety of reds and some pinks.
- **20 minutes No. 9:** A limited range of colours seen in a moderate colour development that consisted of 2 blue and 2 mauve amongst a variety of reds and pinks.
- **30 minutes No 8:** A moderately low development of colours. A scattered number of 3 blue, 3 mauve, 2 violet amongst a variety of reds and pinks.

**Conclusion:** A limited colour range seen with low potential at this high temperature and medium time development.

**Figure 81**

**Group 3: Section 0**

Temperature/Heat development range: @ 550 degrees Celsius

Time taken for colour development 180 minutes

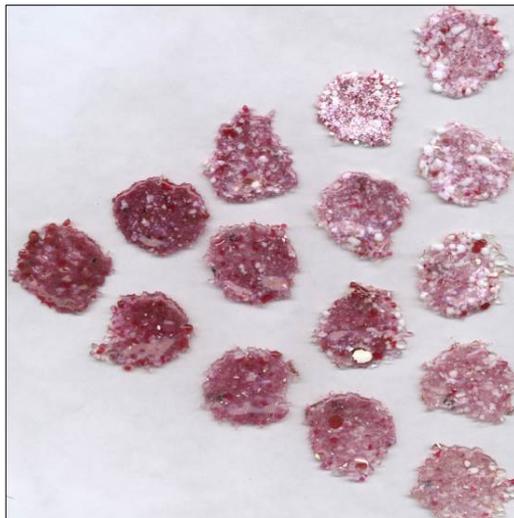
Ultraviolet light exposure range: 30, 20, 10 and 5 minutes.



**Triaxial No: 7.**  
UV exposure: 5 minutes  
Heat development: @ 550 degrees Celsius  
for 180 minutes.



**Triaxial No: 6.**  
UV exposure: 10 minutes  
Heat development: @ 550 degrees Celsius  
for 180 minutes.

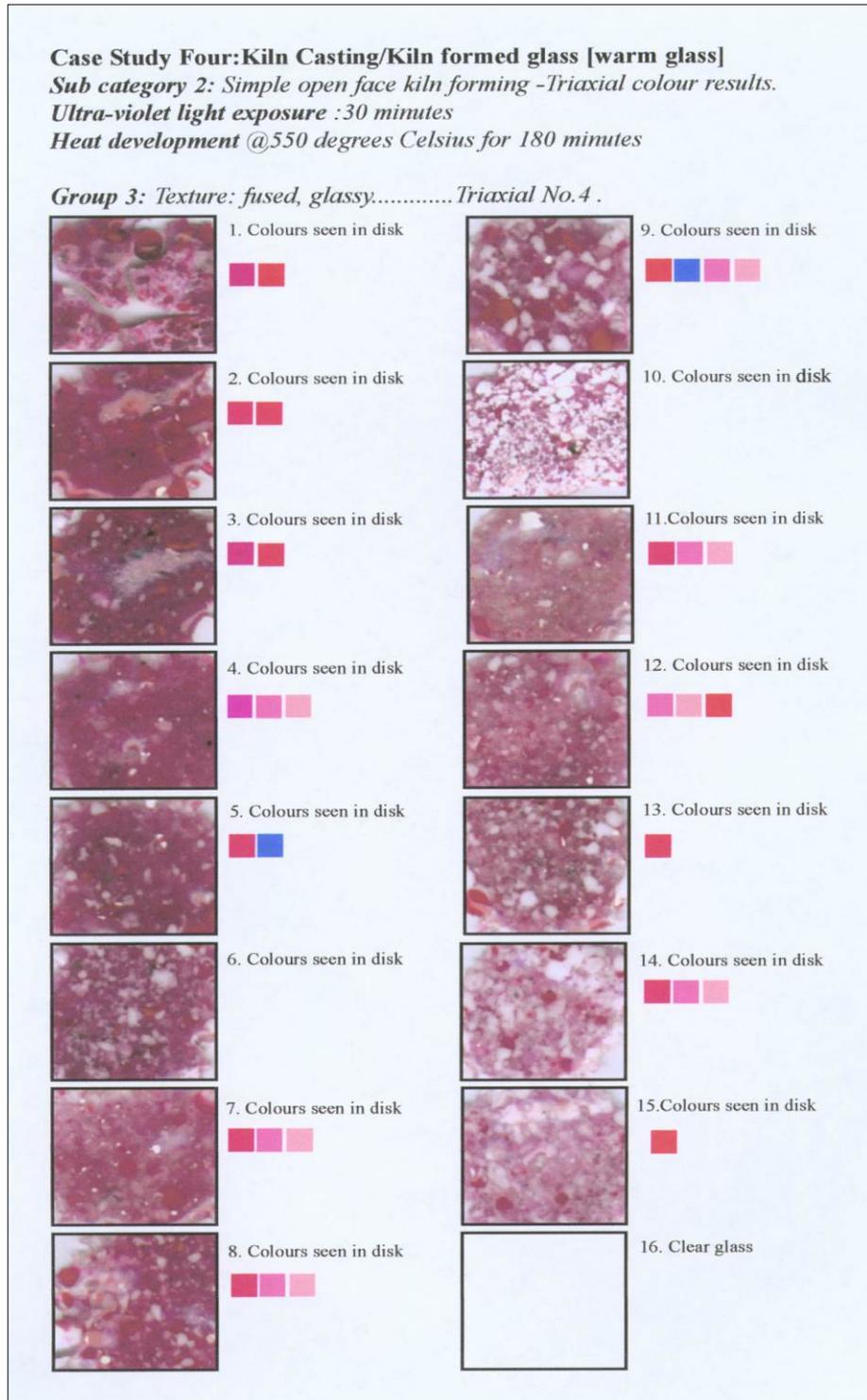


**Triaxial No: 5.**  
UV exposure: 20 minutes  
Heat development: @ 550 degrees Celsius  
for 180 minutes.

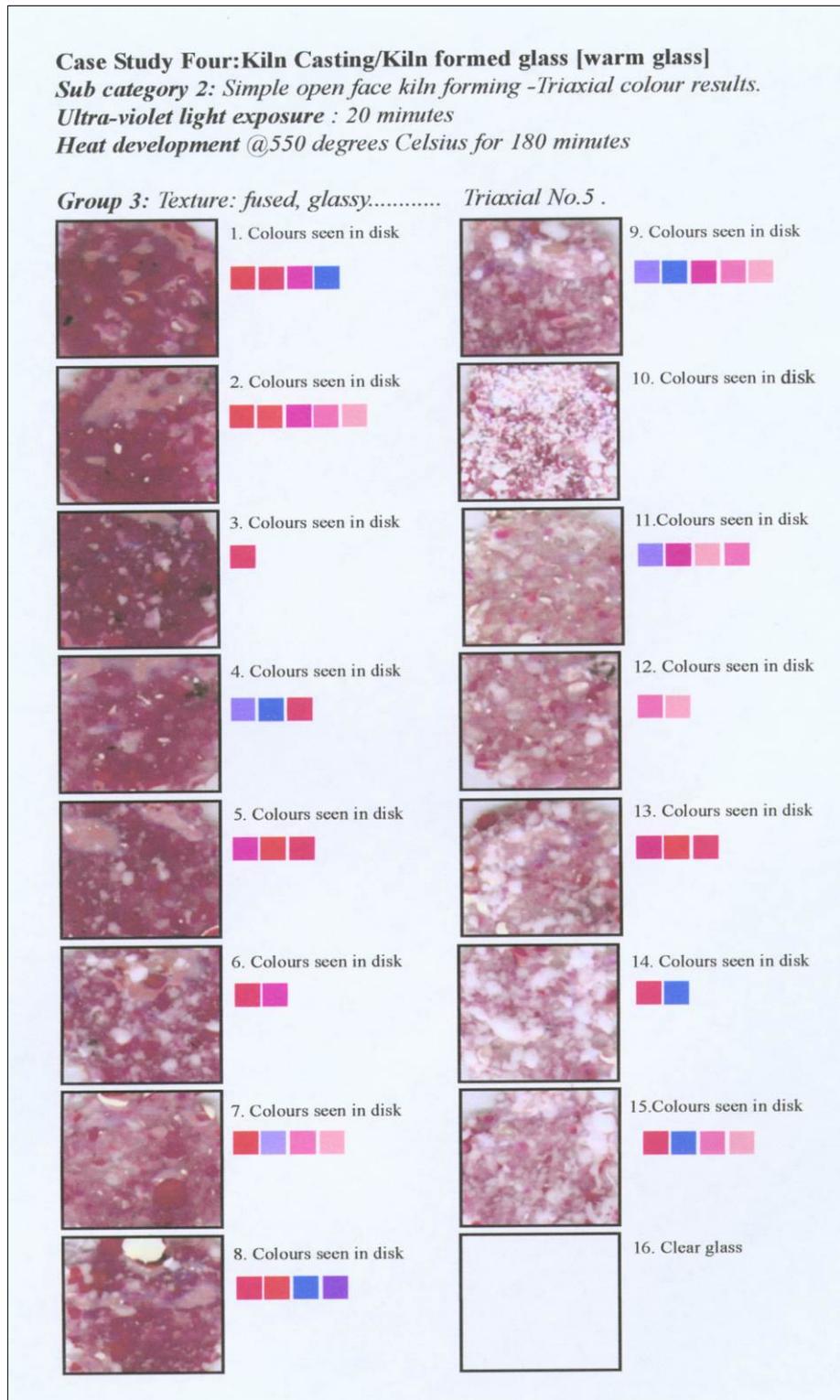


**Triaxial No: 4.**  
UV exposure: 30 minutes  
Heat development: @ 550 degrees Celsius  
for 180 minutes.

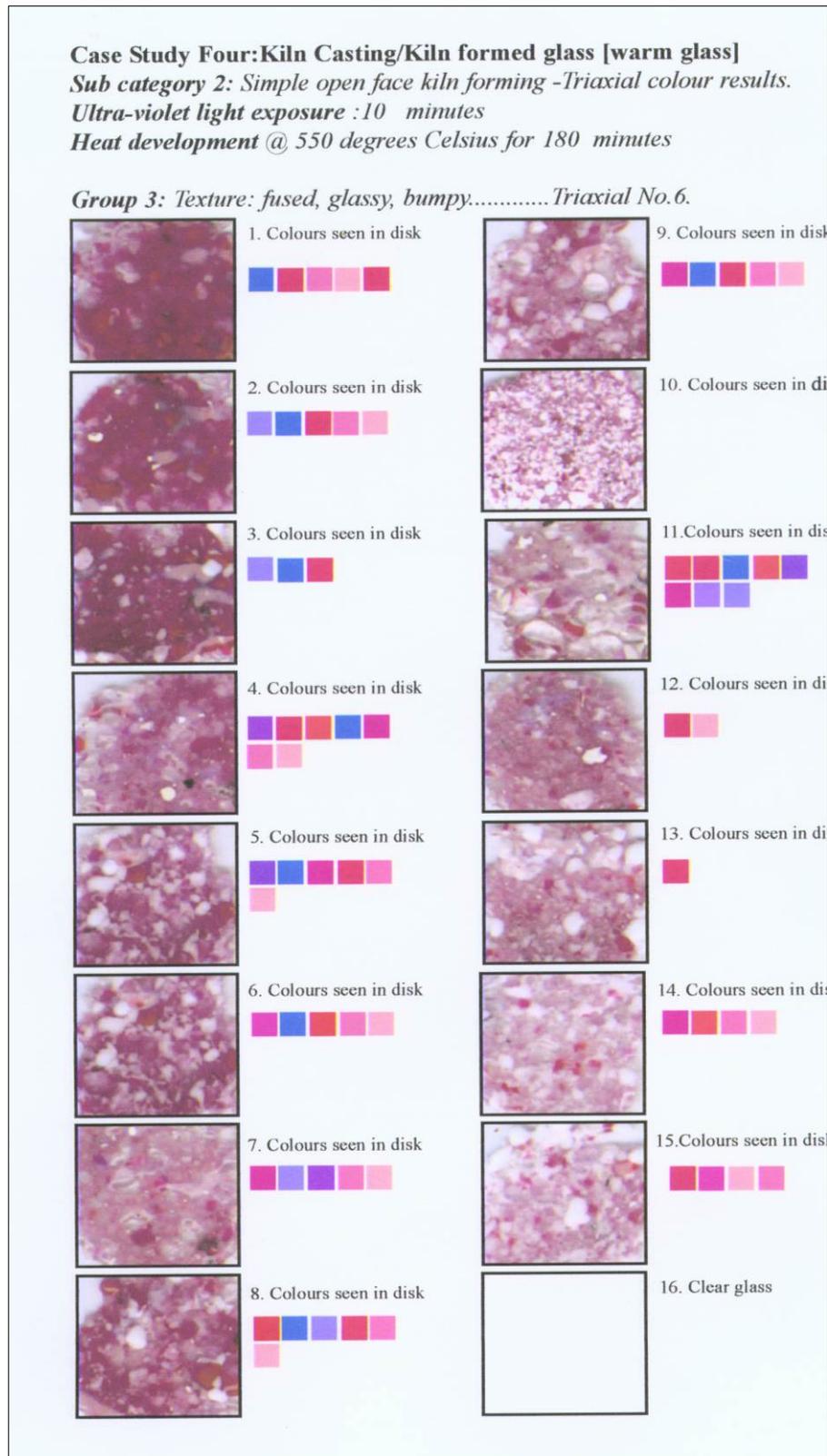
**Figure 81a** (Triaxial No. 4)



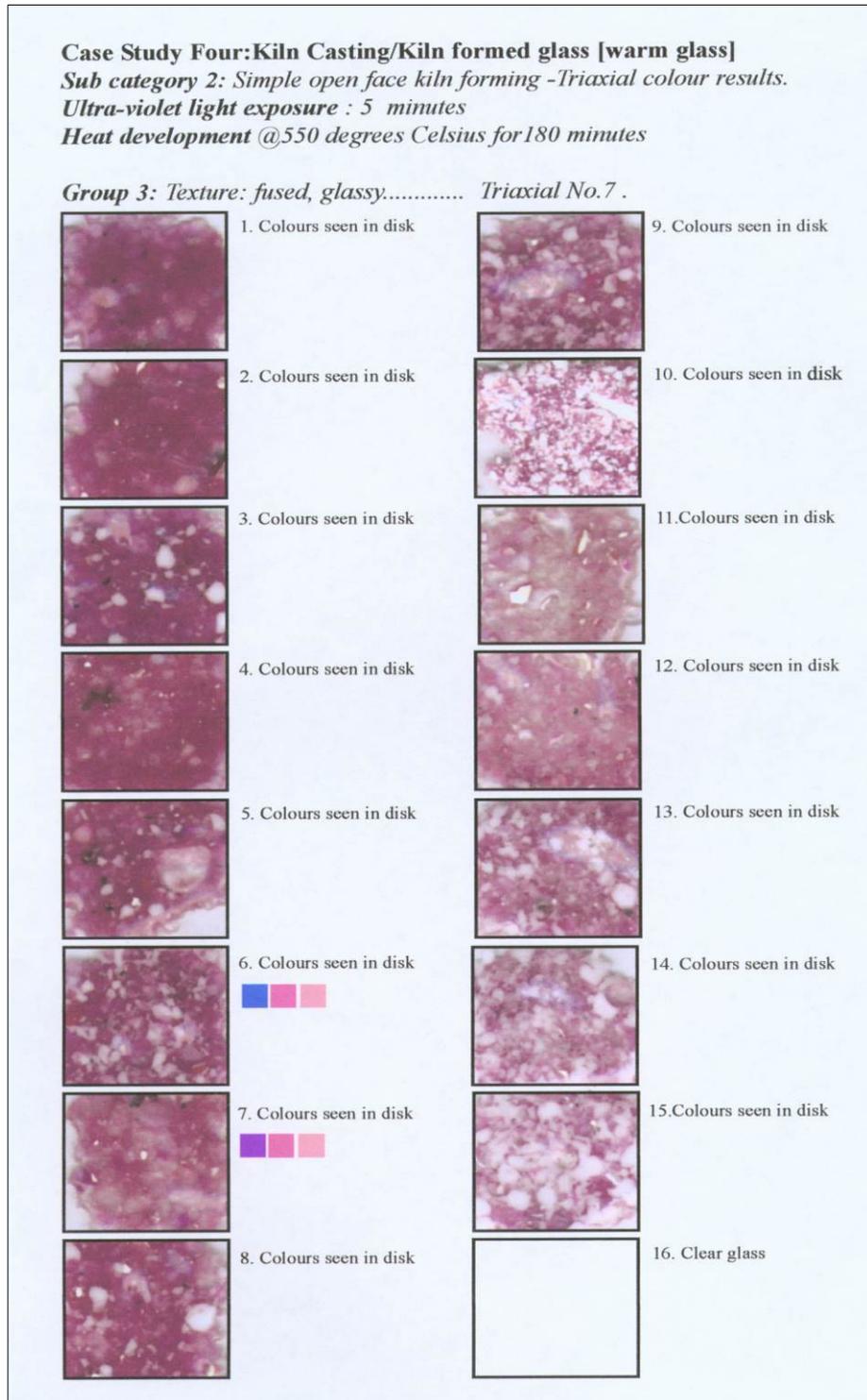
**Figure 81b** (Triaxial No.5)



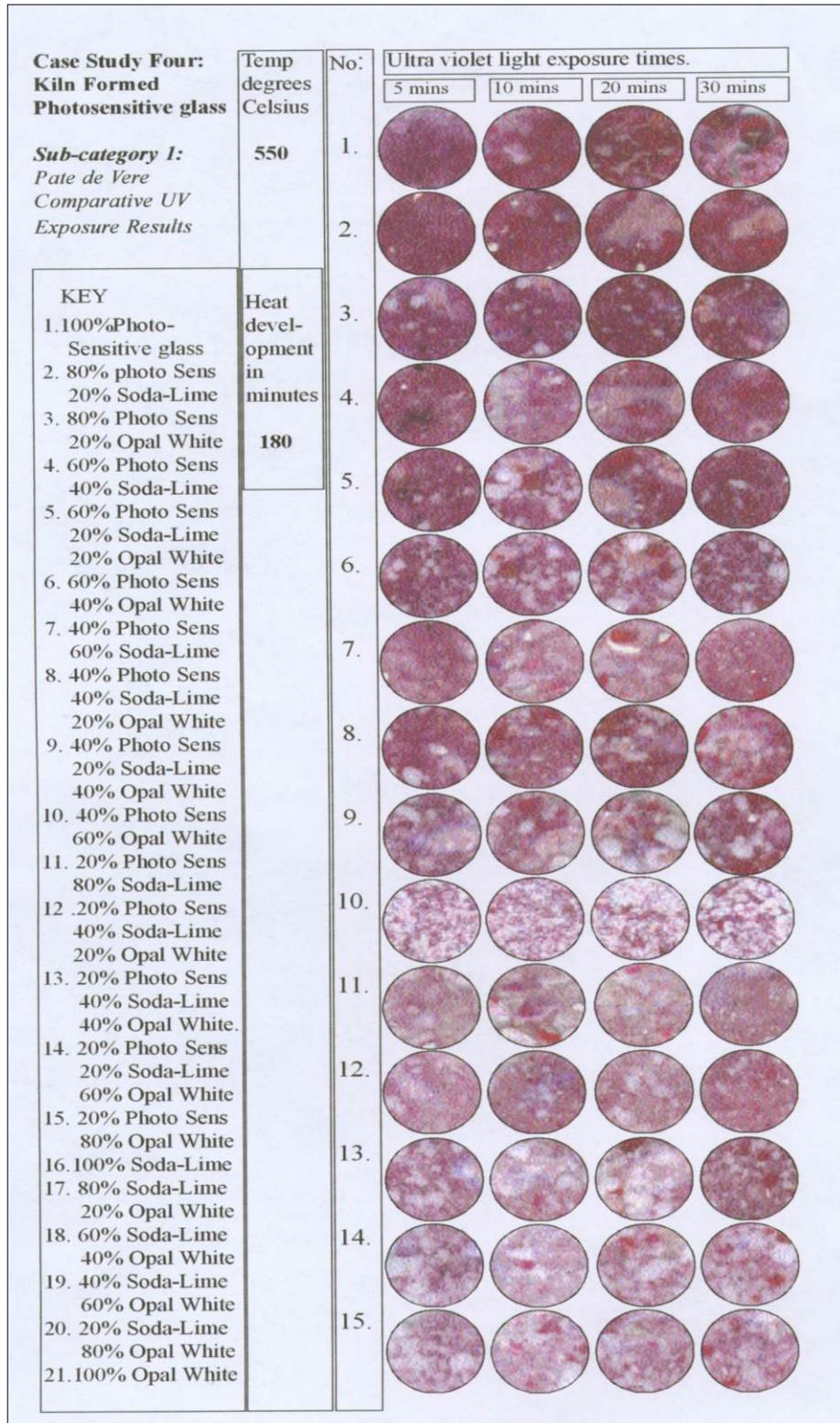
**Figure 81c** (Triaxial No.6)



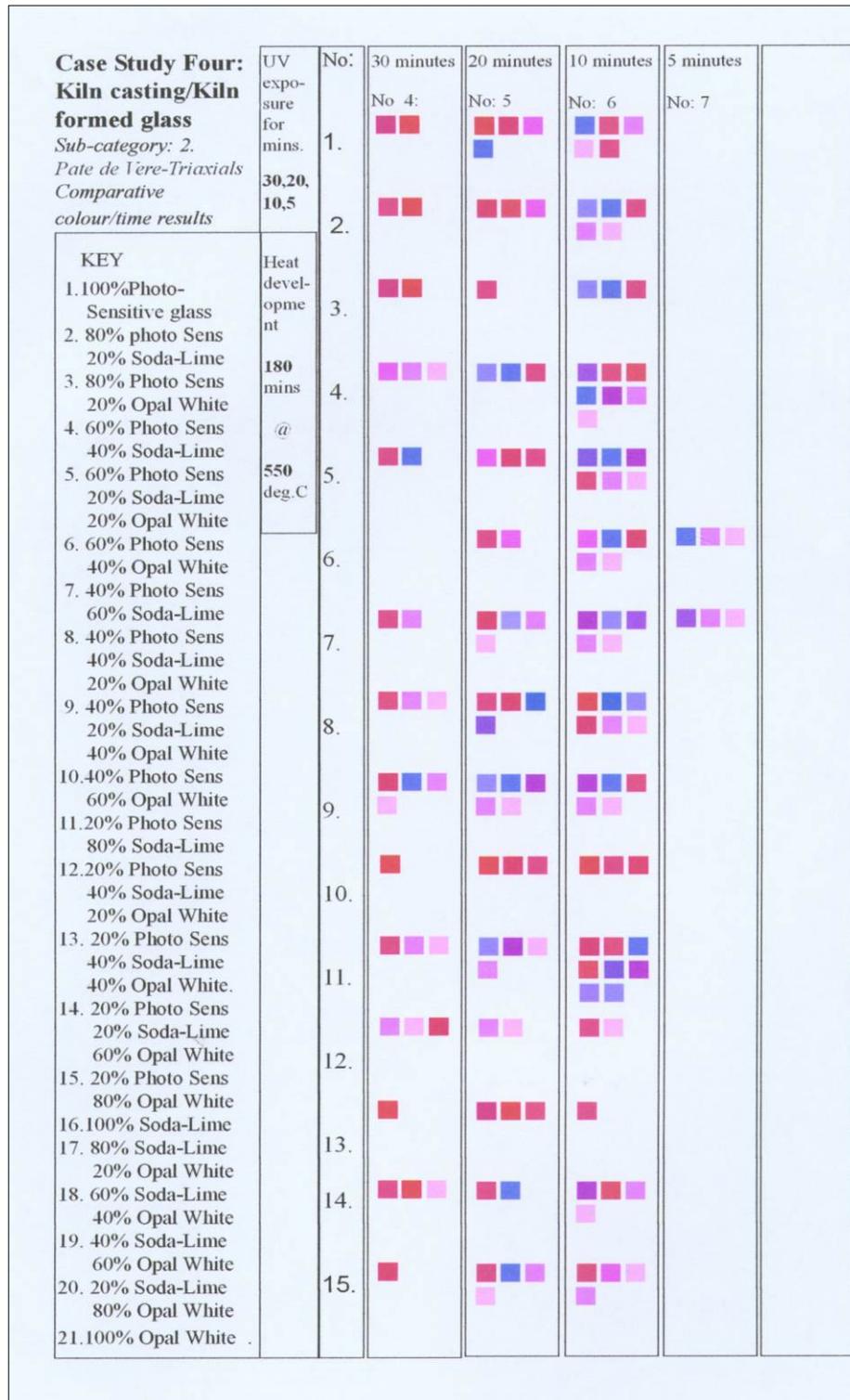
**Figure 81e** (Triaxial No.7)



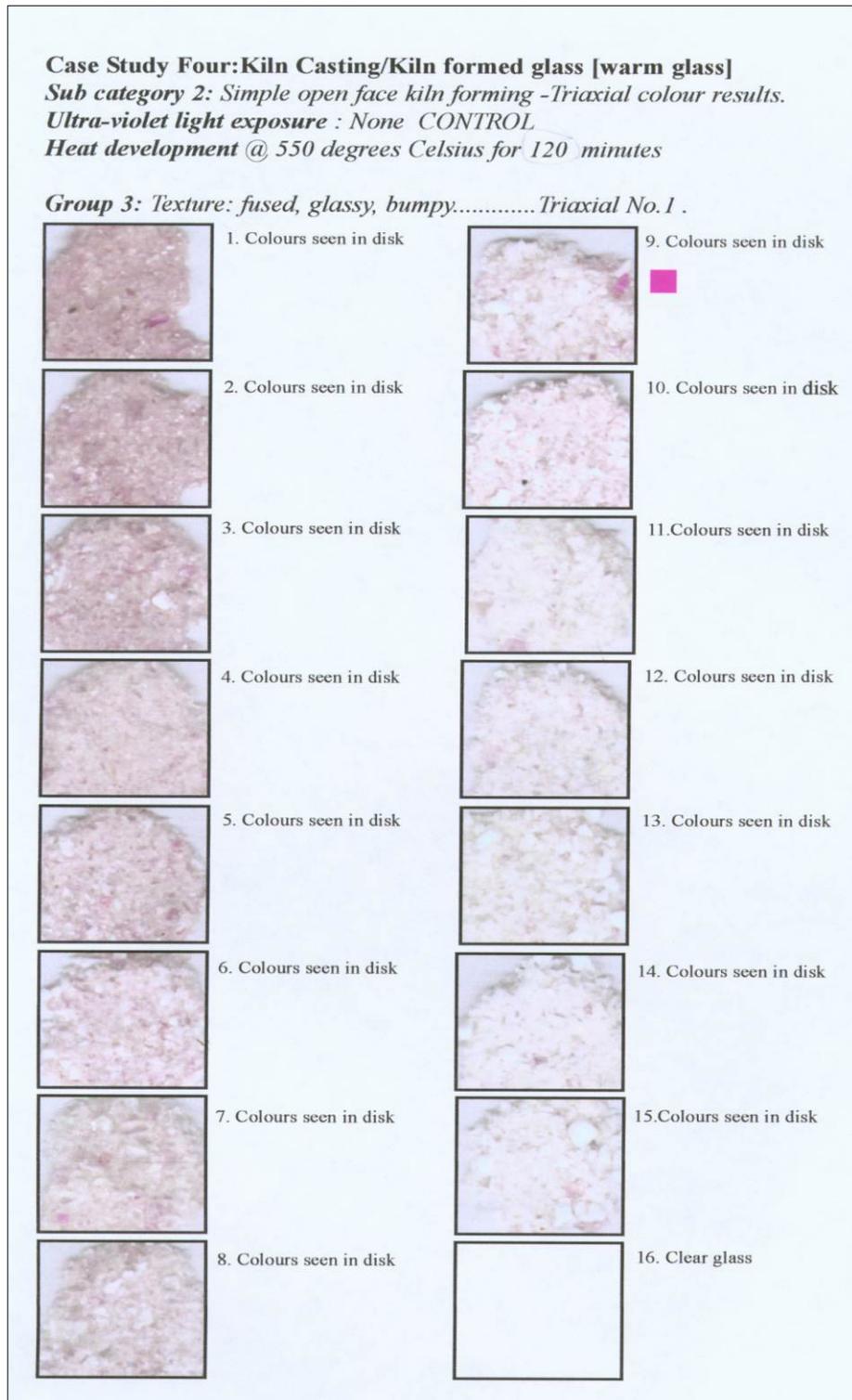
**Figure 81d** (Comparative timed UV exposure results)



**Figure 81f** (Comparative colour/time results)



**Figure 81g CONTROL @ 550 degrees Celsius for 180 minutes. (Triaxial No. 1)**



## **Analysis of Figure 81**

Section 0: for 550 degrees Celsius for 180 minutes developing time.

- **UV exposure:**
- **5 minutes No. 7:** A very low colour development. Disks number 6 and disks number 7 were the only two disks to show any colour development.
- **10 minutes No. 6:** A moderate to good development of strong colours. 9 blue, 6 mauve, 4 violet and 2 orange were seen amongst the variety of reds, pink-reds, orange-reds, orange-pinks and a variety of pinks.
- **20 minutes No. 5:** A low to moderate development limited to 6 blue, 4 mauves, and 1 violet. These colours were seen amongst the variety of reds, pink-reds, orange-reds, orange-pinks and variety of pinks.
- **30 minutes No 4:** A low to moderate development. The colours that developed were limited to mainly reds, orange/red pinks, and one blue. Here the colours were quite strong in their intensity.

**Conclusion:** A limited potential for colour development for No. 4, and No.5 for 20 minutes ultraviolet light exposure. No. 6 exposed at 10 minutes shows some potential at the high temperature and 180 minutes long timed development.

## **Discussion**

Because most of the interesting and unusual colours occurred at the lower temperatures of 490, 495 and 505 degrees Celsius, group 1 is much larger than group 2 and group 3.

Each triaxial consisted of 21 disks. Each disk was enlarged so that the colours which had developed could be seen on the computer screen.

The developed colours could be seen by the naked eye when the disk was held up to sunlight or bright electric light. Alternative viewing of the developed colours was seen by the naked eye by placing each disk on a photographic light table.

Examples of the triaxials can be seen in all figures numbered Xa, Xb, Xc, Xe, and Xf.

The triaxials were given numbers according to their temperature, UV exposure and timed heat development position in the kiln then each disk according to its position in the triaxial was given a number to correspond with the ingredients it contained. An ingredient key adjacent to the diagram labeled comparative timed UV exposure results of each triaxial as can be seen in all figures labeled X with a 'd' appendage.

The disks were then gently cleaned and placed in their triaxial positions in the Umax Power 11 scanner. The dpi was set at 1000 and the entire triaxial was scanned starting with figure 78 and ending with figure 92.

Following the scanning of a triaxial, each disk was individually scanned so that it could be enlarged. For the purpose of analyzing the triaxial, each group of triaxials had a comprehensive table. This comprehensive table contained the original scanned disk information. Each disk corresponded with its number in the triaxial and was illustrated in a separate illustrative box with coded colour bars that indicated the colours seen in the disk. These numbers corresponded with the position of the disk in the original triaxial and with the ingredients contained in the disk.

Coded letters to identify the various colours seen in each disk were written above each colour coded box for future comparative reference. Only fifteen of the disks were presented as the disks at base of the triaxial were colourless. The textures of the disks in each triaxial was noted and recorded.

## **Methods and procedures for collecting data:**

### **Data sources**

Data was sourced visually from the physical disks and from the scanned results of the disks from each triaxial blend experiment. Each triaxial disk was held up for viewing by daylight. The colours that were present within the disk were noted before placing the disk onto a photographic light table for further visualization. Detailed notes were made of the colours that appeared in each disk when on the light table. In some instances, colours seen with the naked eye in day light differed from the colours seen by the naked eye on the photographic light table.

### **Data presentation issues**

The issue of presenting the data was to print them as they looked to the naked eye when scanned into the computer and printed out in table form. These original triaxials were scanned and were presented in alphabetically numbered sections of a group. For example Figure 88.

This type of presentation did not indicate what colours had developed in the disks so the data was then additionally presented in the form of comparative colour coded linear tables with coloured squares alongside each numbered disk. For example Figure 88a (triaxial No.22). These coded colours were observed by enlarging each disk so that the hidden developed colours could be seen.

Ultra-violet light exposure times, heat development times and the selected temperature ranges were recorded.

### **Presentation analysis**

**1. Comparative timed ultraviolet exposure results tables as illustrated in all figures with a d appendage** were drawn up showing ultra violet light exposure times of 5, 10, 20 and 30 minutes. The numbered disk results of all the triaxial experiments were placed into the four numbered circular spaces that corresponded with the ultraviolet light exposures. The temperature of the ultraviolet light exposure experiments was placed in a heat development column that showed the temperature that each triaxial was heat developed at. Below the temperature entry, the length of time taken to develop the particular triaxial was recorded.

**2. The coded comparative colour/time results tables: involved all figures with f appendages** complemented the comparative timed ultraviolet exposure results table discussed above and indicated the numbers of the triaxial at the top of the columns. The time that the triaxial underwent ultraviolet light exposure, the temperature and time that the triaxial was heat developed for and the colours seen in the disks were illustrated as coloured squares and printed out in columns that corresponded with the circular columns containing the images of the disks in the comparative timed ultraviolet exposure results.

**A set of comparative heat development results tables** was drawn up. These tables showed five columns for circular spaces for entry of the temperatures of 490, 495, 505, 525, and 550 degrees Celsius. The numbered disk results of all the triaxial experiments for the above temperatures were placed between the ultraviolet light exposure time column (above) and the heat development time column (.below). The heat development times ranged from 90, 120, 180 and 240 minutes.

**A set of colour coded comparative heat development tables** was then drawn up to correspond with the five circular spaces discussed above. Each table showed a triaxial number at the beneath each temperature column. Below the triaxial number in the heat development temperature column, opposite one of the fifteen disk numbers, a number of coloured squares indicate the colours I saw in the disk. The time each triaxial took at the heat development stage is entered below the timed ultraviolet light exposure column.

The comparative heat development results tables and the corresponding colour coded comparative heat development tables were printed on the same page for comparison. By referring to the comparative heat development tables and the corresponding colour coded comparative heat development tables that indicate a common ultraviolet light exposure, a balance of the colours needed or wanted can be selected. These tables start from Figure 82a and 93b and can be viewed in Appendix Cvii (a) in the Appendices CD Rom that accompanies this thesis.

### **Criteria for the interpretation of the results**

The criteria for the interpretation of the data results were the ultraviolet exposure times, the heat development times and the heat development temperatures of the triaxial experiments and the variety of colours seen in each enlarged triaxial disk. By using the triaxial blending and the line blending processes, a systematic experimental framework has been achieved that will meet my objective of how

much photosensitive glass is needed to develop weak colour, medium colour and strong colour and any other unknown special colour results.

### **Comparative colour coded heat/time developed results**

Tables were designed to illustrate my analytical colour coded results.

Colour coded interpretation of each disk in the triaxials was a way of illustrating what colours had developed according temperature/time. Each table consists of a single ultraviolet light exposure and heat development time and a numbered ingredient list alongside five columns of heat development temperatures. The coded letters interpreting the colours seen were entered according to number in each column and correspond with the coded colours placed alongside the scanned illustrations of the disks as described in the research procedures heading.

### **Data interpretation and analysis**

The data were analysed by comparing the results of the colour coded colour/time results with the coded colour/heat results and then cross referenced according to the times the data were exposed to ultraviolet light. Data interpretation was made by reading along the number of the disk in the colour coded comparative ultraviolet light exposure and timed heat development results table. These colour coded comparative ultraviolet light exposure tables showed the results that were obtained by the length of time the triaxial disks were exposed. These numbered visual ultraviolet light exposure results could then be compared with the disk that corresponded to the same number shown in the comparative time and heat development table and analysed. The colour coded data were then placed into five or four columns according to their temperature development rates and could be compared.

### **Potential application**

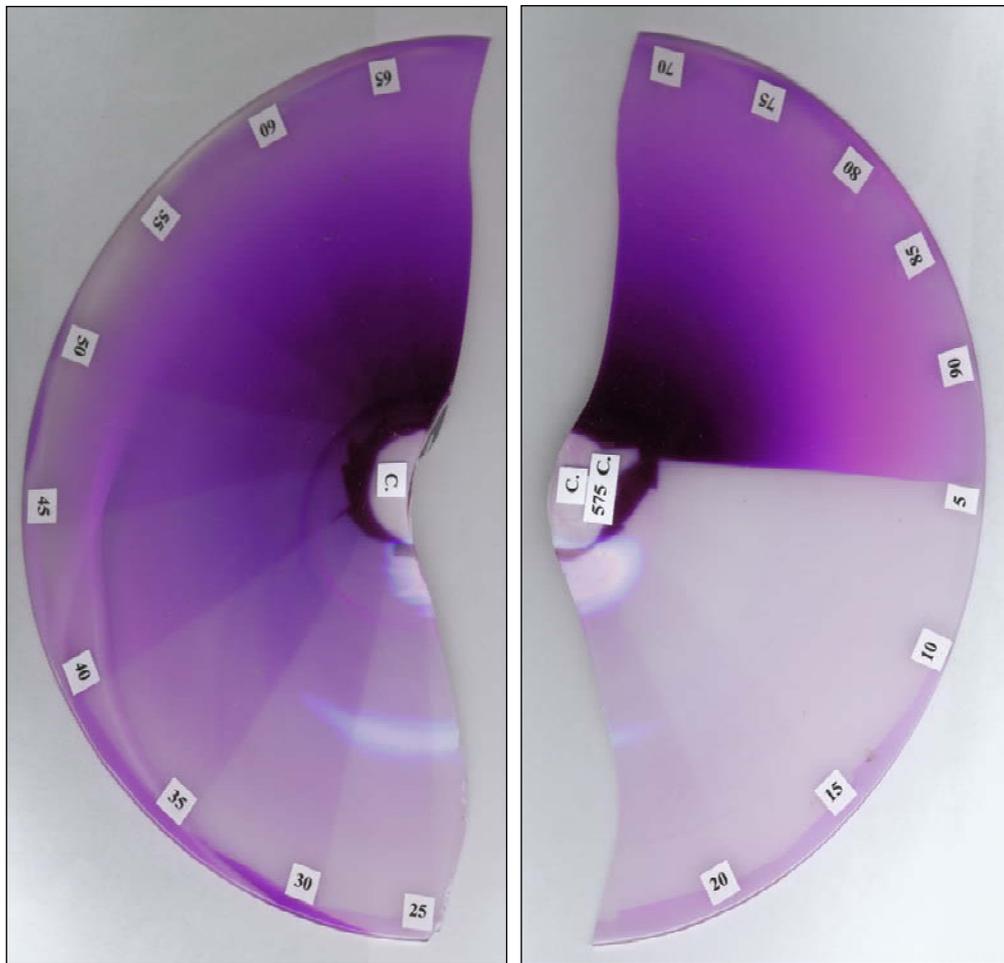
Cross referencing the colours that I could see in the disks with the times of ultraviolet light exposures and the temperatures that the disks were heated up to and the length of time it took for the heat development stage was important so as

to be able to obtain comparative colour results. The purpose of these colour coded tables was to be able to read the colours available in each disk at a given ultraviolet light exposure across a range of temperatures and heat development times. This facility will be useful when making a prototype because some will need heating for longer times at certain temperatures. The potential application of these experimental results depends upon the interpretation of the colour coded table results by the glass artist working in the genre of Pate de Vere.

### **Overview**

Making Pate de Vere using the results of my experimental triaxial blending method has delivered an unexpected wide range of choice for the incorporation of photosensitive glass into this glass making technique. Further experimental research could be done at the lower temperatures of 490 degrees Celsius and 505 degrees Celsius using ultraviolet light heat development exposures between 5 and 10 minutes and again from 11 minutes to 19 minutes. Additional heat development temperatures and time settings could be considered by a future researcher.

Case Study Six:  
Sub-category 5.6.1.  
Free blowing: Crowns, Bullion, Disks.



*Disk c: UV exposed: 5 to 90 minutes.  
Heat developed: @ 575 degrees Celsius for 270 minutes.*

## **5.6.0. Case Study Six: Free blown glass and blowing a bubble into a mould (Hot glass)**

### **Sub-category 5.6.1: Free blowing**

The two factors that were the starting point for my continued experimentation in case study six were the initial scoping experiments based on the scoping experimental kiln firing schedules using the small disks of photosensitive glass and the proposed but discontinued scoping experiments in making Bullion or Crowns by glass artist Jasper Dowding in Chapter Five. The knowledge that it was possible to place a photograph or image into photosensitive glass encouraged me to continue with the research into making Bullion or Crowns. I was interested in concentrating on examining and documenting photosensitive glass as a case study of materials research for art practice

### **6.1.0d. Systematic Experimentation**

Experiments in the following section include eight photosensitive glass disks (bullion or crowns) grouped into a control group of four disks and a variable group of four disks. Photosensitive glass blown and incased (sandwiched) between blown soda lime furnace glass were made for my research by David Hay of Hyaline Hot Glass Studio. David Hay was my collaborating glass artist who took over the role of Jasper Dowding and blew the disks.

*“Bullions were the major source of window glass for centuries before the cylinder method emerged and became popular because of the large panes which resulted. They are now not often used except for restoration work and for the production of antique types of glass panes”.* (Bray, C. (edit) 2001, 85).

#### **Objectives**

The objective of these experiments was to develop eight graded tonal coloured photosensitive glass disks (bullion or crowns) that could be used as a reference for

blown photosensitive art glass works based on different time and heat development temperatures after having been exposed to ultraviolet light.

### **Designing the experiment**

It was necessary for me to find out how to mathematically calculate the amount of photosensitive glass needed to make a disk of a certain size (diameter) from a rod of photosensitive glass. The first step was to measure the diameter of the rod of photosensitive glass. The second step was to decide on the diameter of the blown disk. Selecting the thickness of photosensitive glass in the disk was the third step. In a personal communication from Dr. Eric F. May (2006) N.I.S.T. Maryland, Washington DC, USA, the method of calculating the amount of photosensitive glass was given to me as follows:

In measuring the diameter of the photosensitive glass rod and estimating the diameter of the proposed glass disk. The volume of a cylindrical rod is

$$V_{rod} = \pi d^2 L / 4$$

where the diameter and length of the rod are  $d$  and  $L$ , respectively. The volume of the thin disk is

$$V_{disk} = \pi D^2 t / 4$$

where the diameter and thickness of the disk are  $D$  and  $t$ , respectively. The fraction of glass originally in a rod that is retained once it is converted to a disk is  $k$ ; for example if 5 % of the glass is lost then  $k = 0.95$ .

To work out the rod dimensions required to produce a disk of given diameter and thickness:

$$V_{disk} = k V_{rod}$$

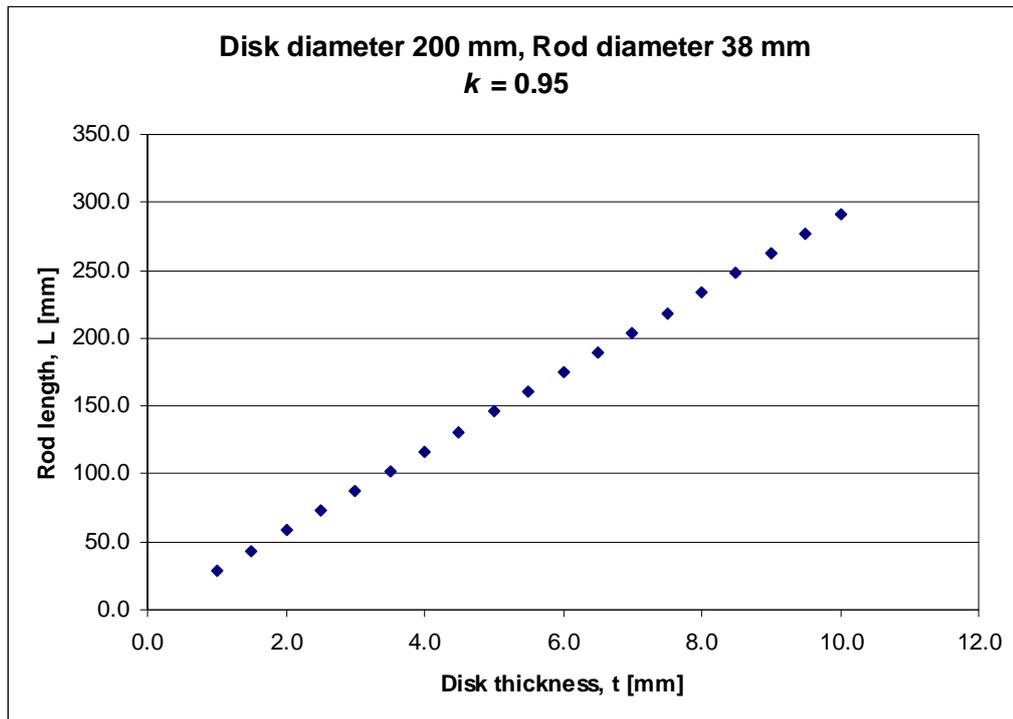
$$\pi D^2 t / 4 = k \pi d^2 L / 4$$

To calculate the length of a rod with given diameter required to create a disk of specified thickness and diameter, the formula is

$$L = (t/k)(D/d)^2$$

Below is an example for a disk diameter of 200 mm, a rod diameter of 38 mm and  $k = 0.95$ .

Rod diameter d [mm]	Disk diameter D [mm]	Disk volume as a fraction of rod's volume k
38.0	200.0	0.95
Disk thickness t [mm]	Rod Length L [mm]	
1.0	29.2	
1.5	43.7	
2.0	58.3	
2.5	72.9	
3.0	87.5	
3.5	102.1	
4.0	116.6	
4.5	131.2	
5.0	145.8	
5.5	160.4	
6.0	175.0	
6.5	189.5	
7.0	204.1	
7.5	218.7	
8.0	233.3	
8.5	247.8	
9.0	262.4	
9.5	277.0	
10.0	291.6	



Once the three steps had been taken, their measurements were used for calculating of how much of the photosensitive glass rod would be needed for a blown disk at a certain thickness.

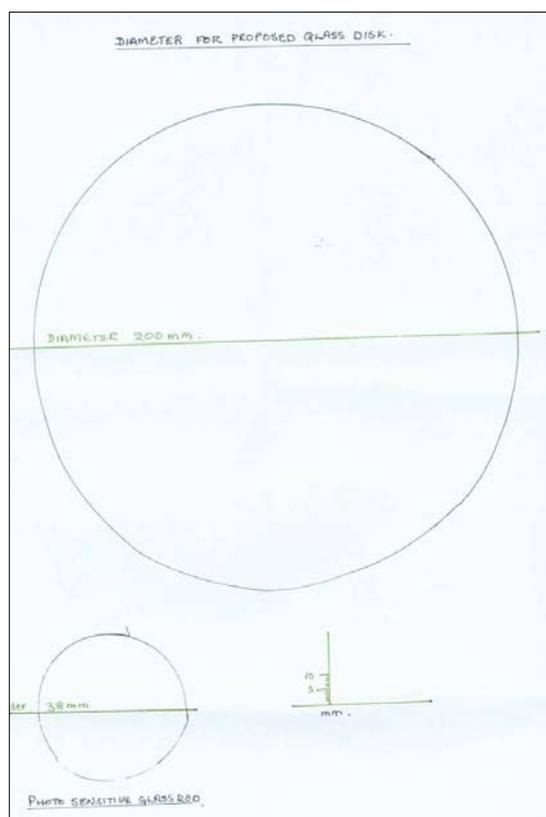
The fourth step taken was to print out the mathematical calculation spreadsheet and calculate three degrees of thickness for glass variations for the experiment. The fifth step was to take the photosensitive glass rod and mathematical calculation spreadsheet to David Hay who expertly cut off the required medallion of photosensitive glass for each disk that need to be blown.

Two groups of four photosensitive glass disks were blown and they were placed in a Lehr kiln and annealed according to David Hay's blown ware annealing schedule. The first group consisted of 'clear' photosensitive glass; this was the planned 'control' group. The second set of disks, the 'experimental group', had a variable in the form of an (d) added colour layer as an '*outside casing*' or backing to the photosensitive glass.

The eight blown disks were carefully wrapped under safe red photographic light in black tissue paper. Care was taken to separate the clear control group of four disks from the variable group of disks. Each group was placed into a black plastic sleeve until ready for experimental exposure under ultraviolet light in the light box. All discarded pieces of photosensitive glass that shattered off the blowing pipe were collected and stored in a light safe lidded tin for future random experimentation (playing with the excess material or recycling).

**Figure 98**

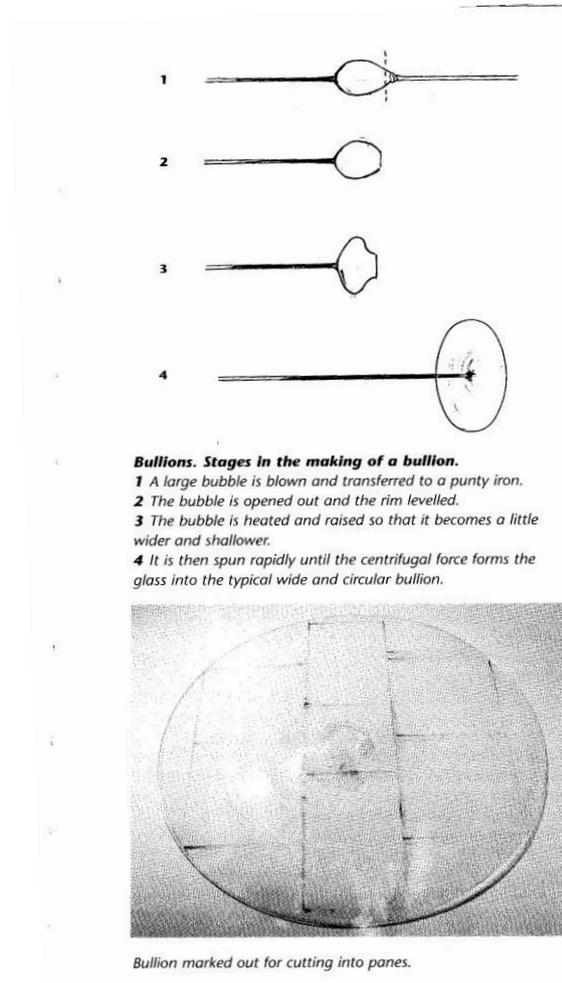
Calculation of the amount of photosensitive glass needed for making a glass disk (crown or bullion).



*Diagram showing the diameter of a proposed photosensitive glass disk and the diameter of the photosensitive glass rod needed for the calculation of the amount of photosensitive glass when making a disk (crown or bullion).*

## Figure 99

Stages in the making of a glass bullion, crown or glass disk.



*Diagram showing the stages in the making of a glass bullion. (Bray C.(edit) 2001,58). Dictionary of Glass: materials and techniques. A & C Black (Publishers) Ltd, 37 Soho Square, London W1D 3QZ.*

### **Testing the hypothesis by action**

The timed 'pie-slice' subtractive method was selected because of the shape of the disk (bullion or crown)

Process details of this case study can be seen in Appendix Cvi (Chapter Six) Case Study Six.

### **Heat development**

A range of four heat development temperatures was selected for the Control and the Variable (d) disks (bullion or crowns). The thickness of the photosensitive glass in the eight disks was 5mm in the centre to 1 mm at the edges.

### **Bullion/Crown disk experiments**

The eight blown photosensitive glass disk experiments were divided into two groups. The following timed heat development experiments were made on the eight blown photosensitive glass disks. The temperature range was from 525 to 600 degrees Celsius and the length or rate of time taken to hold the experiment at a particular temperature was 271 minutes (4hrs 30 minutes).

#### **Control Disks.**

Disk 1-Heat development temperature 525 degrees Celsius for 271 minutes

Disk 2-Heat development temperature 550 degrees Celsius for 271 minutes.

Disk 3-Heat development temperature 575 degrees Celsius for 271 minutes.

Disk 4-Heat development temperature 600 degrees Celsius for 271 minutes.

#### **Variable (d) Disks.**

Disk A - Heat development temperature 525 degrees Celsius for 271 minutes.

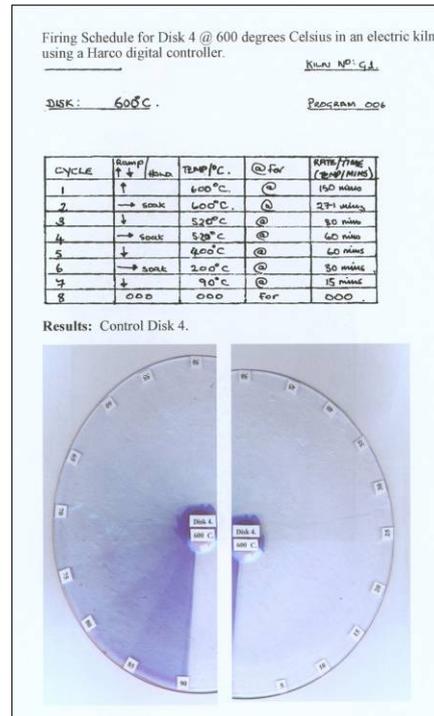
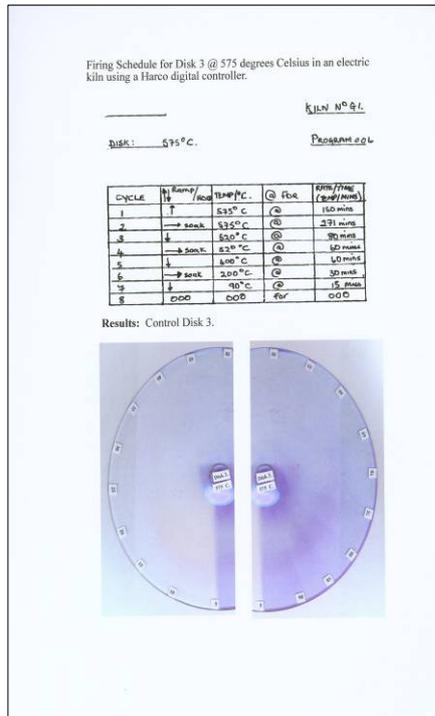
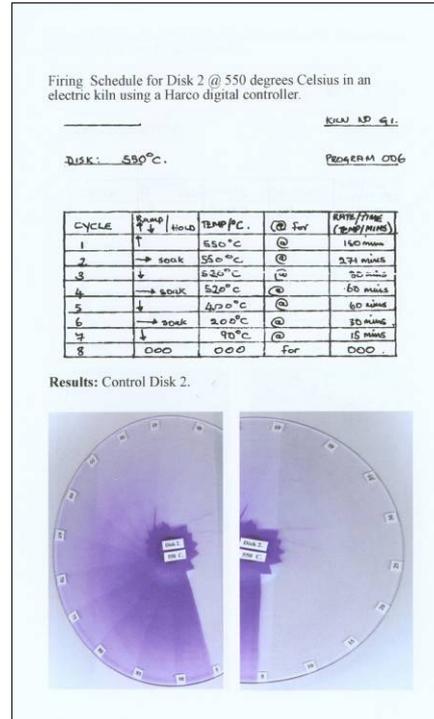
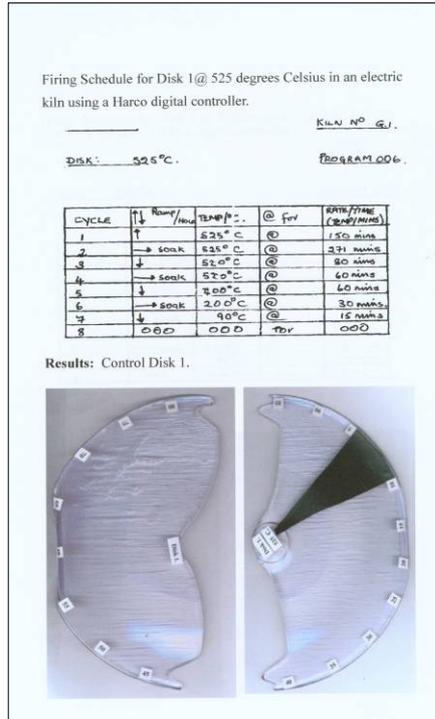
Disk B - Heat development temperature 550 degrees Celsius for 271 minutes.

Disk C – Heat development temperature 575 degrees Celsius for 271 minutes.

Disk D – Heat development temperature 600 degrees Celsius for 271 minutes.

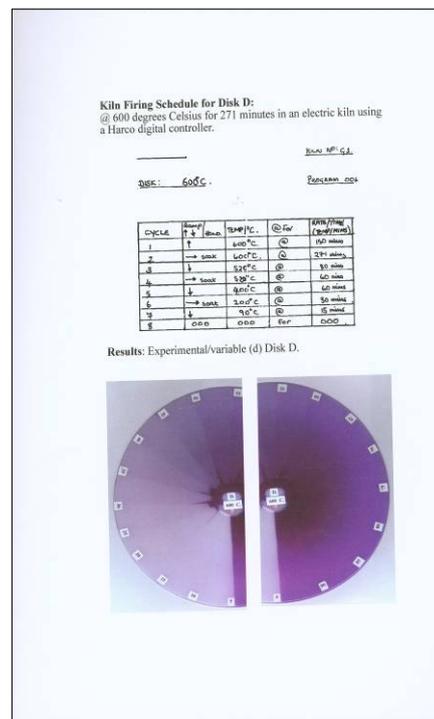
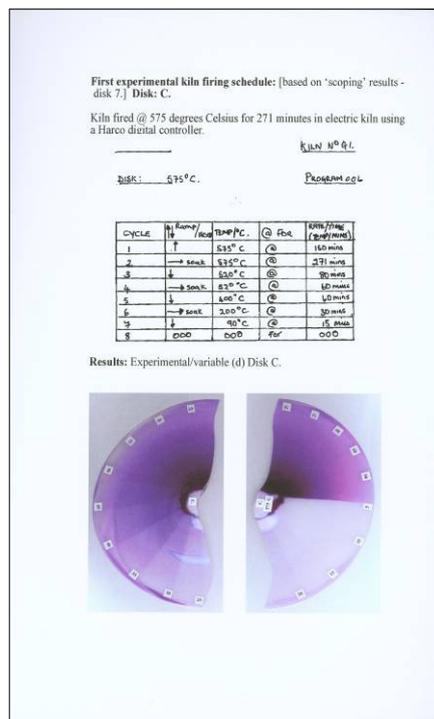
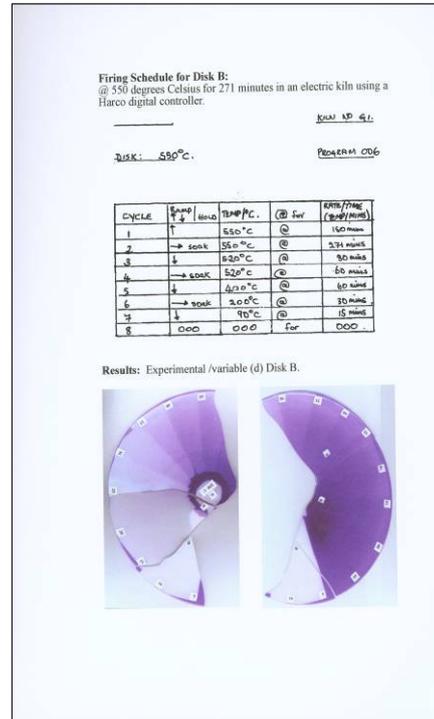
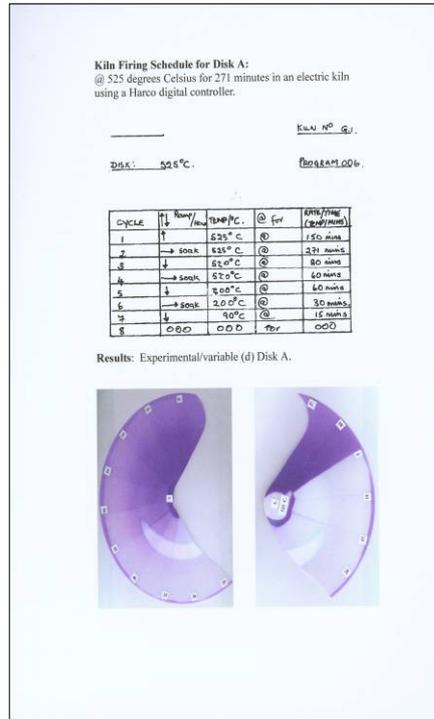
**Figure 100**

Four kiln firing schedules for the Control group of photosensitive glass disks.



**Figure 101**

Four kiln firing schedules for the variable group of photosensitive glass disks.



**Figure 102**

Comparative colour development table of the four control group photosensitive glass disks with the four variable (d) group disks.



## **Overview and Outcome**

The successful systematic experimentation for the incorporation of photosensitive glass into the traditional technique of blown glassware resulted in eight graded tonal coloured photosensitive glass disks. These eight graded tonal coloured photosensitive glass disks can now be used as a reference base for future blown photosensitive glass art-works and for making crowns or bullion. There were four control disks and four variable (d) disks.

The best colour development results occurred using the experimental variable (d) disks. This variable was based on the success of Disk 7 in the scoping experiments in Chapter Five. The colour used for variable disks (d) was Gaffer #101 Opalescent White. These results were compared with the experimental control disks.

## **Potential application**

Potential application of the bullion/crowns could be in the stained glass area as well as in the architectural glass area.

## **Application of the results**

To apply the colour results shown on each disk of to future designs on work being produced using photosensitive glass it is important to compare the colours of ultraviolet light exposure times at specific heat development times for certain periods of time before deciding on the glass technique to be used such as fusing, slumping. If the blown glass piece is required to remain as it was blown, then note the development temperatures and corresponding colour exposures and the time it took to develop the desired colours. Too long a period at heat development may result in the desired colour but will cause the piece to distort. Suit the depth of colour to the length of time to preserve the shape and integrity of the blown glass piece.

In Chapter Seven I discuss the research question and summarize the potential outcomes of the research

## CHAPTER SEVEN

### 7.0.0. DISCUSSION AND CONCLUDING SUMMARY

*‘Can photosensitive glass be made more accessible to artists working in art-glass, design or art practice?’*

This experimental research project was chosen because there appeared to be a gap in the technology of glass-art design and glass-art practice and the question of how to incorporate photosensitive glass into some of the traditional art-glass making techniques interested me. To have significance outside my own interests, I anticipated that this research would contribute to the knowledge and skills of the glass designer/artist as well as the architect/designer wishing to expand their knowledge in the field of glass-art.

The potential research development focus was the interface between the broad fields of art-glass design, art, science and the technology of alternative photographic printing processes. This concept was based on Petrie’s model for sector development (Petrie 2007, 1). In my research, this interface between the fields was a space where I could focus on a specialist area, the niche area of photosensitive glass.

The key aim was to investigate by using the experimental form of the scientific method, how selected traditional glass making techniques and this particular glass technology of the 1950s together with the adaptation of old alternative photographic printing processes of the late 19<sup>th</sup> century could then be used to provide new opportunities in creative and innovative glass design practice. Experimentation with the materials, with the view of looking at the aesthetic and technical potential of the materials that could lead to the creation of new innovative industries as well as leading to a new audience and inspire fresh new work with potential economic outcomes.

The objectives of this research are linked to the theoretical framework and the methodology. Research issues were identified through a contextual literature review which covered a definition of photosensitive glass, the history of photosensitive glass and photosensitive glass process methodology from the specification of the problem in general terms. Sources identified for detailed study are listed in the references section. Innovative combinations of alternative photographic printing techniques such as gum dichromate printing and Cyanotype printing processes were devised. Their adaptation to modern digital technological applications for my research was applied so that they could be used to identify and assess the possibility of using photosensitive glass to enable glass artists/designer to develop new and innovative working processes in order to extend their creative practices. The identification of the range of traditional art glass-making techniques that would benefit from the incorporation of the photosensitive glass making processes was attempted made possible by working as a participant observer and assistant to glass maker/artist David Hay at Hyaline Hot-glass Studio on a regular basis (once a week from March 2003 – to August 2007 and at irregular intervals during 2008). In addition further identification of several potential art-glass techniques suitable for the incorporation of photosensitive included participation in glass making workshops and demonstrations involving the various techniques and processes as well as collaboration with other glass artists. Attendance at these workshops and demonstrations extended the literature review of glass making and assisted with my preliminary experiments to create scoping experiments using photosensitive glass.

The research styles of data documentation and my methods of data collection were compared and analysed and evaluated to find out if the outcomes of the process and materials based research could demonstrate a successful relationship between art, design, industry and scientific technology. To begin with, several traditional art-glass techniques were selected and these selected techniques were subjected to several random methods of incorporating photosensitive glass into the glass making process. Each selected technique was represented in the form of

a case study. Some case studies had multiple sub-categories. These sub-categories were subjected to ‘scoping’ experiments and when their potential was realized, further sequential systematic experiments were carried out. All successful experiments were then systematically repeated before being written up. The experimental results were then analysed and documented. Once documented, the experimental results were compared so as to understand then in order to assess and identify the potential of using photosensitive glass in the fields of architecture, industry, glass-art and design. These processes have been documented in the Appendices so that other glass-art makers will be able to access the information and adapt the findings for their own practice. The outcomes of this research are an original contribution to knowledge about using photosensitive glass in the art-glass field. In addition to the case study experimental results, participant observation and collaboration with other glass artists were used as supportive methodologies and as additional methods for collecting data for my research.

The selected traditional glass making techniques included the categories of hot glass, warm glass and cold glass:

- Pulling of molten glass from a glass furnace to make stringers, canes, rods, murrine and/or mosaics – a hot glass technique.
- Crushing and recycling used photosensitive glass, making Chunk de verre and Pate de verre – a warm glass technique.
- Bead-making, button making, and core-forming – hot glass techniques.
- Kiln work in the form of casting/slumping and simple open face Pate de verre using a triaxial ablending system – a warm glass technique.
- The casting of molten glass from the glass furnace into sand for sand-casting techniques and the forcing of hot molten glass into moulds – hot glass techniques.
- Free blowing and mould blowing – hot glass techniques.
- Acid etching and acid embossing were particularly hazardous cold glass techniques that were only discussed but not attempted.

Case study research extended my experience of working in the cross disciplinary fields of art, design, glass making, photograph and science. This concept is supported by Sue Soy (Spring, 1997) who believes that case study research excels at taking a researcher towards understanding a complex issue that could extend experience or add strength to what is already known through previous research or experience. Researchers have used the case study research method for many years across a variety of disciplines. It is hoped that the outcome of this materials based research demonstrates a successful symbiotic relationship between art, design, industry and science and leads to additional application in other creative fields.

The documentation of art-glass methods, experiments and processes that demonstrates the potential of photosensitive glass as an art medium were analysed to show how it can be an important aspect of art practice today. By using a triaxial blending and line blending process in case study four, a significant systemic experimental framework was achieved that met my objective of how much photosensitive glass is needed to develop weak colour, medium colour and strong colour results. The temperature and time ranges for heat development in an electric digitally controlled kiln for any colour production as well as timed ultraviolet light exposure were explored. The triaxial experiments were analysed and the data were documented to identify methods and processes.

S.Donald Stookey commented that the sub-section of novel photosensitive glass had the potential yet to be proved as an art medium despite the fact that research involving the many applications of photosensitive glass in the scientific continues to flourish. My research was built on his initial inventions, experimentation and prediction that photosensitive glass has the potential to be used as an art medium. As a results of this research project I believe that initial experimentation is necessary when using photosensitive glass.

The research problem for the glass artist/designer of how traditional art-glass making techniques can be modified to incorporate photosensitive so as to enable

them to take advantage of its special properties was explored. This was done by situating the research problem in its broadest context (Art-glass) and describing into which sub-section it belongs, then outlining the specification of the research problem in general terms. Because the work was experimental, the outcomes are an original contribution to knowledge in this hybrid field and add some value to the existing knowledge in this area. Innovative applications of the research outcomes, in selected traditional areas of glass making techniques have been created for future exploration. The processes have been documented so other glass makers will have access to the information to adapt the findings for their own purposes. The outcomes of this materials research may contribute to new innovative industries, lead to products for new audiences as well as current audiences and inspire new work with potential new economic outcomes. So as to have significance this research should contribute to the knowledge and the skills of the glass artist/designer as well as the architect/designer. Preliminary interest has been shown by a number of glass artists working at the private Hyaline Hot Glass Facility, Edith Cowan University, Mount Lawley, Western Australia for this applied research.

I make the argument about the opportunity for glass artists/designers to incorporate photosensitive glass into their traditional glass making techniques and prove that its use in art-glass can be innovatively creative as it has been found to be in contemporary scientific research. This research demonstrates a changed dynamic, where experimentation can take the lead and open up a new avenue of special art-glass.

### **Areas for further development**

It is difficult to predict future outcomes regarding the use of photosensitive glass. The areas of possible experimentation can only be suggested and further research for the use of photosensitive glass is anticipated in the following areas:

- Modern lighting such as Chihuly-like assemblages using differential heat development.

- Photosensitive sheet glass for architectural application (the United Nations Building is faced with hundreds of square metres of photosensitive glass (Bryan 1995, 344).
- Modern lighting such as Chihuly-like assemblages using differential heat development.
- Printing within photosensitive glass.
- Etchability of photosensitive glass for sculptural application.
- Stepped patterned surfaces for visual effects.
- Moire patterns and interference colours.

Further experimental research could be applied within the ultraviolet light exposure times and the subsequent heat development temperatures and times. In particular I suspect that further interesting potential results might occur if the ultraviolet light exposure times were applied between one and five minutes, between five and ten minutes, from eleven minutes to nineteen minutes to the photosensitive glass. Heat development temperatures could then be applied to the above suggested ultraviolet light exposure times at temperatures ranging between 495 degrees Celsius and 499 degrees Celsius, from 501 to 504 degrees Celsius, from 506 to 519 degrees Celsius and between 52- to 524 degrees Celsius. Heat development times could similarly be experimented within all the combinations of ultraviolet light exposures, development temperatures and times. The suggested experimental areas for further research could then be applied to all the case studies and their sub-categories.

In summary, this materials based experimental research, with a core research question combining art, design, alternative photographic printing processes, technology and science has a contextual place in creative art-glass/design practice. Judged in terms of the hypothesis and the research question, it can be reasonably be concluded from the results of the case studies described that the research has been successful. Can photosensitive glass be as innovatively creative in art-glass/design and art practice as it has been found to be in contemporary scientific research?

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## **GLOSSARY**

### **Acid etching** (see etching)

Technique developed in the 18<sup>th</sup> century to give glass a satin matt, shiny or frosted finish by exposing it to hydrofluoric acid. Areas not be etched were covered by an acid-resistant protective layer (wax, varnish or oil) into which a design was scratched before the acid was applied. Also used on cameo glass to remove areas of the overlay (Sotheby 2005: Glass glossary).

### **Acid polish**

Polishing or frosting the glass by dipping in hydrochloric or hydro sulfuric acids (dangerous endeavor) (Kohler 1998: Glass glossary).

### **Alkali.**

In glassmaking, a soluble salt consisting mainly of potassium carbonate or sodium carbonate. It is one of the essential ingredients of glass, generally accounting for about 15-20% of the batch. The alkali is a flux, which reduces the melting point of the major constituent of glass, silica (Corning Museum of Glass: Glass dictionary 2002 - 2010).

### **Annealing.**

A process involving heating and gradual cooling of glass in an annealing oven (lehr) that toughens glass and reduces internal stress (Klein and Ward1992).

A phase in the firing program that encompasses the final stages, from maintenance cooling (the annealing point) until the glass reaches room temperature (Beveridge, Ignase and Pascual 2005: Glass glossary).

### **Bead.**

A round ball, usually with a hole in the center, formed by winding molten glass around a wire. The tendency of glass is to form a round ball when heated (Kohler 1998: Glass glossary).

### **Blowing**

The process of shaping a molten mass of glass by blowing air into it through a blowpipe (Klein D & Ward L 1992). Technique of shaping a molten mass of glass by blowing air into it through a blowpipe, either freehand or into a mold of two or more parts. It was first developed in the latter part of the 1<sup>st</sup> century BC (Sotheby 2005: Glass glossary)

### **Blowpipe**

A metal tube used to gather a blob of molten glass and through which air is blown by the glass-maker into the glass to shape it. A hollow metal tube, about 1.5m (5 ft) long; and 2cm, (3/4 inch) in diameter, with a mouth piece at one end and a thin ring fitted to the other that helps to retain the gather of molten glass from the pot. Air is blown through the mouthpiece to inflate and form the glass (Sotheby 2005: Glass glossary)

**Cane**

A thin rod of clear or colour glass, used to make the stems of certain type of glasses or that is cut in slices and used in the manufacture of *millefiori*, murrine or mosaic glassware Klein and Ward 1992).

**Casing**

Technique of forming two or more layers of glass to make cameo glass. A hollow blank of the outer layer is made before a gob of the inner background is blown inside it. The two then fuse as they are inflated together (Sotheby 2005: Glass glossary).

**Cast glass.**

A technique of making pieces or objects, generally heavy ones, in which the glass takes on the shape of a mold cavity (Beveridge et al 2005: Glass glossary). Made from the 8<sup>th</sup> century BC by fusing powdered frit in single or interlocking molds (Sotheby's glass glossary 2005).

**Casting.**

The generic name for a wide variety of techniques used to form glass in a mould (Corning Museum of Glass: Dictionary 2002-2010).

**C.O.E. (Coefficient of expansion).**

A number that indicates the rate of expansion, per degree of temperature increase, of glass as it is heated. COE is a term frequently used by fusers and glass casters because only glass with close to the same COE can be successfully fused together. If glasses with different COE's are mixed, the glass is said to be incompatible and will not fuse properly (Klein and Ward 1992).

**Core.**

The form to which molten glass is applied in order to make a core-formed vessel. In pre-Roman times, the core is thought to have been made of animal dung mixed with clay (Corning Museum of Glass: Dictionary 2002-2010).

**Core-forming**

A technique dating from 1500BC, in which a vessel is made by trailing molten glass around a shaped core of mud or clay and sand mixed with dung, the core being removed after annealing. Type of glass dating from 15000 BC (before the invention of blowing) whose method of manufacture involves shaping trails of molten glass over a core of mud or clay (sometimes supported by a metal rod) and fusing them together in the furnace. After annealing the core was scraped out. Made in the form of *alabastra*, *amphoriskoi*, *aryballoi* and other vessels (Sotheby 2005: Glass glossary).

**Crown glass**

Sheet glass made by blowing a bubble of glass, cutting the bubble open and then rotating it rapidly on a rod, with repeated reheating, until it formed a flat disk. The glass was then annealed and panes of the required shape cut from it. The process which was known to the Romans produced the ‘bulls-eye’ panes of medieval glass, which were from the centre of the sheet where the rod had been attached (Klein and Ward 1992).

**Crucible or Pot.**

A fire-clay container in which a batch of glass is fused and kept molten in a furnace. The glassworker gathers glass directly from the pot (Corning Museum of Glass: Dictionary 2002-2010).

**Etching, acid etching.**

A technique in which controlled exposure of the surface of glass to hydrofluoric acid results in shiny, matt or frosted decoration of the exposed area. Decorating the surface of (usually thin) glass articles by means of scratching with a diamond-point or treating with acid (Hallam 1996: Glass notes glossary).

**Flaming.**

A technique of exposing solid pieces of photosensitive glass to the flame in the glory-hole in order to work the glass (May, Heather. 2010).

**Flashing**

Gaffer Glass describes photosensitive glass in their catalogue of glass rods for glass blowers as a transparent “flashing” colours glass. It is classed as thermal contraction compatible (tested with a trident seal) with typical generic lead and soda lime based glasses and is internationally recognised.

**Free-blown.**

Formed and shaped solely on a blow-pipe. Another term for hand-blown (Sotheby 2005: Glass glossary).

**Furnace.**

An enclosed structure for the production and application of heat. In glassmaking, furnaces are used for melting the batch, maintaining pots of glass in a molten state, and reheating partly formed objects at the glory hole (Corning Museum of Glass: Dictionary 2002-2010).

**Fuse.**

Bonding or melting together different pieces of compatible glass by means of heat (Kohler 1998: Glass glossary).

**Full fusing.**

Operation carried out with heat, in which the glass melts completely, the layers thin out, and the edges become completely rounded (Beveridge, P., et al 2005: Glass glossary).

**Fusing**

Technique based on joining two or more kinds of glass. Fusing is a generic term including various techniques with the common characteristic of creating flat pieces by superimposing various kinds of glass (Beveridge, P., et al 2005: Glass glossary).

**Gaffer**

The head glass-maker, sometimes called a master blower, who does the most skilled work (Sotheby 2005: Glass glossary).

**Gather.**

The blob or mass of molten glass attached to the blowpipe or pontil before an object is formed from it (Klein and Ward 1992).

**Glass.**

Homogeneous material which has a random, liquid-like (non-crystalline) molecular structure (Sotheby 2005: Glass glossary 2005).

**Glassblowing.**

Glass gathered on the end of a blowpipe and formed into a variety of shapes by blowing air through the blowpipe into the molten glass (Kohler 1998: Glass glossary).

**Glory-hole.**

A high temperature chamber used for reshaping glass either on a punt rod or blow pipe (Klein and Ward 1992).

**Graal glass.**

A type of ornamental glass developed in Sweden in 1916. It was made by cutting and etching a pattern on coloured glass and then returning the piece to the furnace to give the design fluidity before encasing it in clear glass (Klein and Ward 1992).

**Kiln.**

An oven used to process a substance by burning, drying, or heating. In contemporary glass working, kilns are used to fuse enamel and for kiln-forming processes such as slumping (Corning Museum of Glass:Dictionary 2002-2010).

**Kiln forming.**

The process of fusing or shaping glass (usually in or over a mould) by heating it in a kiln. See also Slumping(Corning Museum of Glass:Dictionary 2002-2010).

Glass that is shaped in an electric or gas kiln by casting, fusing or slumping (Kohler 1998: Glass glossary).

**Lampwork.**

Glass either blown or manipulated from clear or coloured glass rods over a torch or blow lamp, used in papers weights and Nevers figures (Sotheby's glossary 2005).Any glass-working technique done with the direct flame of a torch; work with pre-formed glass rods and tubes (Sotheby 2005: Glass glossary ).

**Lehr.**

Oven used for annealing glass (Kohler 1998: Glass glossary).

**Mandrel**

Term used in glass bead-making to describe the wire or rod around which a bead is wound (Kohler 1998: Glass glossary).

**Marver.**

An iron or table upon which the gather is rolled into an evenly shaped mass, in a process known as 'marvering'( Klein and Ward 1992).

**Marvering.**

Technique of rolling hot, softened glass over a flat surface (a marver) in order to smooth out the vessel, to consolidate trailed decoration applied to the vessel or to pick up decoration in the form of blobs or fragments of glass (Sotheby 2005: Glass glossary).

**Moil (Moyle)**

The unwanted top of a blown object. When the last stage in the forming process is the removal of the object from the blowpipe, the result is a narrow opening that almost certainly is not what the glassblower desires. After annealing, therefore, the top of the object is removed, usually by cracking off. The moil (moyle) from a mould-blown object is often known as an overblow. (Corning Museum of Glass: Dictionary 2002-2010).

**Mould.**

A form used for shaping and/or decorating molten glass. Some moulds (e.g., dip moulds) impart a pattern to the paraison, which is then withdrawn, and blown and tooled to the desired shape and size; other moulds ( sometimes known as full-size moulds) are used to give the object its final form, with or without decoration. Dip moulds consist of a single part and are usually shaped like beakers. Full sized moulds usually have two or more parts and can be opened to extract the object. Nowadays, most moulds are made of metal, but stone, wood, plaster, and

earthenware moulds were used in the past and are still occasionally employed today (Corning Museum of Glass:Dictionary 2002-2010).

**Mosaic.**

Pre-formed, sliced canes of glass placed around or in a mold, heated slowly until the elements fuse together to form the required shape and then polished when cold to smooth the surface (Sotheby 2005: Glass glossary).

**Mould blowing.**

Inflating the paraison of hot glass in a mould. The glass is forced against the inner surfaces of the mould and assumes its shape, together with any decoration that it bears (Corning Museum of Glass: Dictionary 2002-2010.)

**Mould Blown.**

The paraison is blown into a mould, either by hand or as part of a mechanized process (Hallam 1996: Glass notes glossary).

**Murrine** (also spelt **Murrhine**) (Hallam 1996: Glass notes glossary ).

Short lengths or slices of canes (including millefiori), used in mosaic glass, or picked up onto the gather or paraison from the marver before or during blowing, and therefore sometimes smeared or distorted in the finished article.

**Overlay.**

Another term for cased glass (Sotheby 2005: Glass glossary).

**Opalescent glass.**

A glass with a milky, iridescent appearance (Beveridge, P., et al 2005: Glass glossary).

**Paraison.**

The bubble of molten glass formed on the blowpipe after air has been blown into it (Klein and Ward L 1992).

**Pate-de-Verre.**

Literally, '*glass paste*'. A mixture of crushed glass, flux and colour fused together in a mould. The technique of making pieces or objects from ground glass in a mold. The glass is mixed with water or a glue solution to form a thick paste, which is the origin of the technique's name (Beveridge, P., et al 2005: Glass glossary).

French, '*glass paste*'. Ancient technique, revived in France during the second half of the 19<sup>th</sup> century, of melting in a mould ground glass, to which was added a fluxing medium and colouring agent ) this was either powdered, coloured glass or metallic oxide) (Sotheby 2005: Glass glossary ),( Klein and Ward 1992).

**Pontil (punty).**

A solid metal rod used, tipped with a wad or ring of hot glass, to remove a blown object from the blowpipe in order to allow the top to be finished and any other final shaping to be done. When the glass has cooled and solidified it is knocked off the rod, leaving a rough mark, the 'pontil mark' (Klein and Ward 1992). From c 1800 – 1860 usually ground and polished out. (Hallam 1996: Glass notes glossary).

**Prunt.**

A blob of glass applied to a glass object as a decoration, and sometimes drawn to a point or impressed with a pattern (raspberry prunt) or a mask (lion's head prunt) (Klein and Ward 1992).

**Pyrometric cones.**

Small triangular ceramic cones that are made to bend at specific temperatures to indicate the internal temperature of an oven. There are witness cones and junior cones, the latter are used in an automatic shut-off device called a kiln sitter (Kohler 1998: Glass glossary).

**Refractory.**

A substance, usually clay with high silica content, capable of resisting high temperatures. Furnaces and pots are made from refractory materials (Corning Museum of Glass: Dictionary 2002-2010).

**Rod.**

A monochrome segment of glass cut from a trail (Corning Museum of Glass: Dictionary 2002-2010).

**Sand-casting, sand moulding.**

A forming technique in which molten glass is poured or ladled into a mould of compacted sand. A rough textured granular surface results where the glass comes into contact with the sand (Corning Museum of Glass: Dictionary 2002-2010)

**Slumping.**

The process of reheating a blank until it becomes soft and gradually flows under its own weight over or into a former mould and eventually assumes the shape of the mould. Soda lime glass becomes soft at about 600 degrees Celsius (1110 degrees Fahrenheit). Slumping is also known as sagging (Corning Museum of Glass: Dictionary 2002-2010).

**Soda glass.**

Glass in which the alkali is soda (sodium carbonate) rather than potash. Venetian *crystallo* is a soda glass and much soda glassware is in the *facon de Venise style*. The soda was traditionally obtained from barilla. Soda glass remains plastic after heating for longer than either Potash glass or Lead glass, and can therefore be worked into the more intricate forms such as those favoured by Venetian glassmakers (Hallam 1996: Glass notes glossary ).

**Soda-lime glass.**

Historically, the most common form of glass. It contains three major compounds in varying proportions, but usually silica (about 12 – 18%). Soda-lime glasses are relatively light, and upon heating, the glass remains plastic and workable over a wide range of temperatures. The glasses lend themselves, therefore, to elaborate manipulative techniques (Corning Museum of Glass: Dictionary 2002-2010).

**Striking.**

Reheating a glass object in order to develop a colour or special effect, as when making ruby glass or Amberina (Klein D & Ward L 1992).

**Stringer**

Thin strands of pulled hot glass from the furnace (Sotheby 2005: Glass glossary).

**Trail**

Strand of glass, roughly circular in cross section which has been drawn out from a small gather of glass and applied to the surface of the vessel (Sotheby 2005: Glass glossary).

**Trailing.**

The laying of threads or trails of hot glass over a glass object to form a decorative pattern (Sotheby 2005: Glass glossary).

## Appendices

These appendices supplement the main body of the thesis and contain the processes and technical details of the following scoping case study sub-category experiments in Chapter Five and the final successful experiments in Chapter Six. These appendices can be seen on the accompanying CD Rom.

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Appendix Biv (a) refers to Chapter Five: Scoping Case Study Four, sub-category 5.4.1: Kiln casting/Slumping.

Appendix Biv (b) refers to Chapter Five: Scoping Case Study Four, sub-category 5.4.3.: Triaxial blending for Open-face Pate de Verre

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Appendix Cvi (a) refers to Chapter Six: Case Study Six, sub-category 5.6.1.: successful Free blowing Crowns, Disks and Bullion.

Appendix Cvii (a) refers to Chapter Six: Case study Four, sub-category 5.4.3: Pate de Verre Triaxials – comparative colour coded heat/timed development results.

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## **Appendices**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice.**

These appendices supplement the main body of the thesis and contain the processes and technical details of the following scoping case study sub-category experiments in Chapter Five and the final successful experiments in Chapter Six. These appendices can be seen on the accompanying CD Rom.

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## **Appendix Ai (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive Glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Three and contains the processes and technical details of the following: the ultraviolet light box and the Flat bed kin.

#### **Designing the Ultraviolet Light Box**

Because of the distance plus the cost of delivery it was necessary to design and construct an ultraviolet light box suitable for the exposure of photosensitive glass experiments for this thesis.

Pre-experimental action plans were designed and drawn up for the construction of an ultraviolet light box that would fit over an electric potter's wheel head See Figure 9. An ultra violet light box was then made up in the woodwork facility at Curtin University (under supervision) <sup>1</sup>using MDF compressed wood purchased from a hardware shop. Expert help was enlisted from the technician in the workshop of Clay & Glass as well as from the woodwork facility at Curtin University to build the housing box. The interior of the box was painted with two coats of white Wattyl Solar Guard gloss paint. Solar Guard is an ultraviolet light protective paint and gloss was used for reflective purposes. The instructions received from Gaffer glass on delivery of the rods of photosensitive glass were followed with regard to the optimum placing of the objects to be exposed.

Exposure of the photosensitive glass to ultraviolet light requires peak UV radiation, and usually requires considerably more exposure time than ordinary photographic material. The wave length of light required (300-350nm) can be

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<sup>1</sup> Olympic Color Rods, of Seattle, Washington offers Photosensitive Glass Products in their catalogue on page 12. The most expensive item, the G-Sunlamp plus 6ft electrical cord for attaching onto the K-FIXTUR-E-20 or the K-FIXTURE-E40 both 2 ft long, comes with the bulbs included. PCB Equipment – UV Exposure Units advertise three steel framed units for exposing photosensitive glass art work. This company is based in the United Kingdom.

supplied by sunlight (as in gum printing and cyanotype printing) but because exposure under sunlight is considered to be too variable, the results cannot be relied upon. Using a commonly available fluorescent suntan tube gave more consistent results. A Phillips TW40W/09N low pressure mercury vapor fluorescent tube was suggested. Two NEC FL20SBL-24 black-light tubes length 600 mm housed in a double fluorescent light tube frame, attached to the inside top of the light box were chosen. The decision to use two 20 watts black light tubes instead of one 40 watt black light tube was to the black light tubes to be separated so as to expose a vertical photosensitive glass object to ultraviolet light. An additional housing for one black light tube was situated diagonally on the right side of the light box for this purpose. Gaffer (2004) suggested that the optimum distance for an object being exposed, is 100-150mm for about 20 to 40 minutes to achieve most effects. These measurements were penciled on the inside right and left sides of the light box for reference. The instructions suggested using an old record turntable for achieving an even exposure, however a decision was made to use an electronic potters' wheel in lieu of the record turntable, as its speed could be more easily controlled. A red photographic light was placed in a suitable corner of the studio so that the photosensitive glass pieces would not be subjected to unnecessary latent ultraviolet light exposure while placing them on the wheel head. Gaffer (2004) stipulates that after ultraviolet light exposure a '*latent image*' would result. This '*latent image*' result is not visible and must be kept in the dark until development by controlled heat in an electric kiln.

Photosensitive glass contains microscopic particles of metallic compounds such as gold and cerium, so when ultraviolet light passes through a photographic negative onto the glass surface, a latent shadowy image is formed within the glass. When the glass is heated, the latent image is converted into a visible image (Gaffer Glass 2004). The designs of appropriate firing programs were adapted for firing photosensitive glass using *Firing Schedules for Glass: The kiln Companion* by Graham Stone 1999.

## **WARNING - HEALTH AND SAFETY ISSUES<sup>2</sup>**

### **The Eye**

The danger to the eye is enhanced by the fact that light can enter from all angles around the eye and not only in the direction one is looking. UV radiation exposure can damage the cornea, the outer protective coating of the eye. Photokeratitis is a painful inflammation of the eye caused by UV radiation-induced lesions on the cornea. Symptoms include a ‘*sand-like*’ feeling in the eye that can last for several days. The lens can also be damaged and there is reason for concern because cataracts are the direct result of lens damage. Eye protection was worn at all times when there was UV exposure. Eyeglasses should be ANSI-Z87 rated and provide protection from side exposure via a side lens of ‘wrap around’ lens. Normal eye protection, prescription glasses, or contact offer little to no protection.

### **Exposure of the photosensitive glass experiments under ultraviolet light using the photographic subtractive method**

#### **Procedure:**

- Cut up a number of ‘*light resistant strips*’ in a masking material and apply to the glass experiment under safe red light in the dark room.
- Place the experiment onto the potter’s wheel-head secure with Blue tac if necessary.
- Remove the first ‘*strip*’ then
- Lower the ultraviolet light box onto the potter’s wheel frame.

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<sup>2</sup> The main source of UV exposure is the sun. Exposure from the sun is typically limited to the UV-A region, since the earth’s atmosphere protects us from the more harmful UV-B and UV-C rays. However, additional precautions should be taken when working in a laboratory because common lab equipment can generate concentrated UV radiation in all three regions. Ultraviolet radiation is found in biological safety cabinets, **light boxes**, and cross-linkers in many University laboratories and in some patient care rooms. One of the problems in working with UV radiation is that the symptoms or overexposure are not immediately felt so persons exposed do not realize the hazard until after the damage is done. (JABSOM EHSO-UV Radiation SOP 2009, January).

- Set the count- up timer and switch on the ultraviolet light, rotate the wheel under the box using the pedal for this purpose for the set amount of time preferably using a digital timer.
- Switch the ultra violet light off before lifting the box off the experiment.
- Remove the first masking '*strip*' and mark the space with a letter or number to indicate the exposure time.
- Remove the second '*strip*' and continue with the procedure until all the '*strip*'s have been exposed and then removed after marking.
- Wrap the exposed experiment in a black photographic plastic sleeve.
- Place sleeve in a secure dark box until ready for heat development in an electric kiln.

### **Procedures for data collection and analysis**

#### **Procedure:**

- Directly scan the heat developed photosensitive glass experimental results through a photographic scanner.
- Save the scans the program Adobe Photoshop for later digital manipulation.

### **Analysing the data**

#### **Procedure:**

- Compare the colours of the exposure times on the experiments at specific heat development times.
- Decide what glass technique is to be used for example, Fusing or if the heat developed photosensitive glass experiment is required to remain as it was.
- Note the development temperatures and corresponding colour exposure.
- Apply this knowledge to the design of the work being produced.

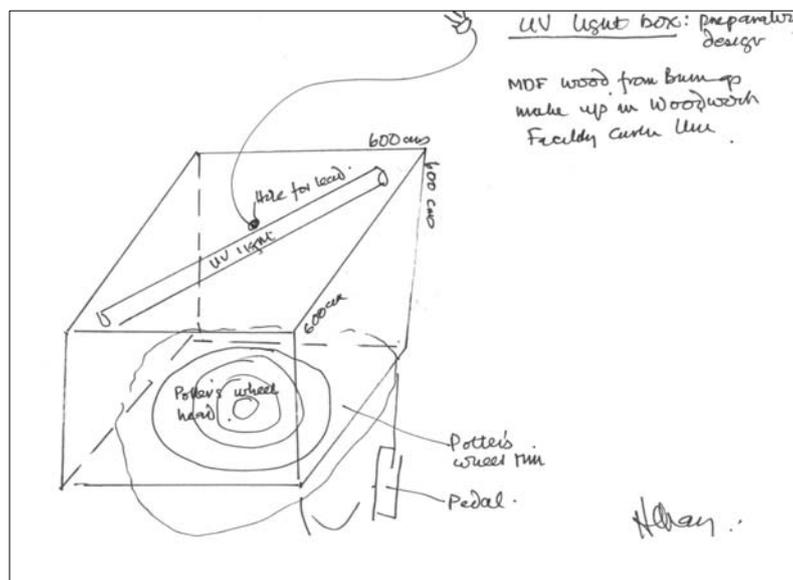
### **Pre-experimental action**

A check-list was made in working note book for designing and setting up the equipment.

#### **Procedure:**

- Design and draw plans for an ultraviolet light box and research ultraviolet light sensitive paints for painting light box then look for locations where to purchase ultraviolet light tubes and frame to fit box
- Construct design for box in woodwork facility at Curtin University
- Then paint two coats of white Solver Exterior inside and outside of the box.
- When paint is dry attach the UV light frame inside of box
- Insert regular fluorescent tubes into frame and test before inserting black light tubes for ultraviolet light exposure.
- Remember to wear suitable protective eyewear to protect eyes from exposure to ultraviolet light.
- Mark up suggested measurements in pencil inside box such as the desired distance of glass object from the ultraviolet light tubes as per instructions from Gaffer glass.
- Place ultraviolet light box on pottery wheel and test for shuddering when wheel is running
- Then set up red photographic darkroom in pottery studio.
- Purchase an electronic count-up digital timer to time exposures.
- then begin the procedure by first setting up a trial run using all the equipment in darkness
- Photograph all the stages of equipment design and record details in daily journal
- Print photographs for research thesis and then write up all relevant details in working notebook.

**Figure: 1.** Diagrammatic drawing of ultraviolet light box.



### **Making refractory crucibles to fit the miniature furnace**

Despite the fact that small crucibles were readily available from suppliers of refractories, the decision was made to construct and produce them and then fire them in the Clay & Glass Workshop.

#### **Technical process**

A bag of Courtland's Cream Raku clay was selected because of the absence of iron in the body and its known behaviour to thermal<sup>3</sup> shock. Crucibles, based on the size and shape of the gold assay beaker that I used in the 'scoping' tests in firing the soda lime glass were made. It was estimated that each crucible would only be used once so as to avoid any contamination of the photosensitive glass.

After preliminary firing to a low bisque temperature in a ceramic kiln 800 – 1000 degrees Celsius, the crucibles were refired and brought to glost

<sup>3</sup> The effect on a material or rapid temperature change. It usually involves the stress which is formed as the surface expands or contracts more rapidly than the interior, often resulting in cracking or complete breakage.

temperature at 1280 degrees Celsius (Eramo 2005, October 27). The homemade crucible was first tested using clear soda lime glass chips so as to insure that there were no cracks or weaknesses in the body.

The next step to be taken was to further insulate the mini furnace so as to prevent loss of heat. The sides of a furnace are often composed of layers of different materials rather than being made from one single type. Several grades of ceramic fibre insulating material were available so this material was selected as a back-up insulation to the refractory bricks (Bray 2001, 142). A large piece of ceramic fibre was wrapped around the outside of the walls of the furnace, leaving a gap for the burner port and secured with refractory wire near the top and the base. A circle of ceramic fibre was cut out with an inner smaller cut-out circle for the crucible hole and attached to the top of the refractory bricks. Wire mesh was then wrapped around the furnace sides and bent inwards at the top to hold the circle of ceramic fibre in situ and lessen the irritant factor. For Health and Safety Issues two coats of Glass kiln wash (25% Kaolin, 25% Silica 25 % Alumina Hydrate plus 25% Zirconium flour) mixed with some water until smooth and creamy were painted over the top and the sides of the furnace to cover the ceramic fibre (Kohler 1998, 52). A ceramic outer jacket was made from Walkers white raku clay to fit around the newly insulated furnace wall. This jacket was bisque fired to 1000 degrees Celsius before the furnace was placed on a large round thick ceramic fibre board. Once on the fibre board, the burner port was blocked off with ceramic fibre board and kiln washed inside before the gap between the insulating fibre and the jacket was filled with vermiculite and perlite horticultural grade beads for additional insulation. The dome was altered to incorporate a small glory hole<sup>4</sup> on one side. This was necessary as glass had to be accessed and gathered onto a miniature punty or blow pipe then re-heated while being worked. One of the beaker crucibles was

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<sup>4</sup> A Glory-hole is a very basic but important piece of equipment used to re-heating hot glass quickly whilst it is being worked. Many are made very simply from a metal drum lined with ceramic fibre open at one end and with a burner placed to fire through the side (Bray 2001, 134).

used to plug this glory hole while the furnace was being fired up to temperature.

### **Technical information regarding my flat-bed kiln.**

#### **Technical process:**

A Flat-Bed electric kiln suitable for my research project was collaboratively designed and then constructed by the technician in the Clay & Glass workshop area of the Department of Art and Design. The structure or shell of the kiln was made from metal. The base of the kiln was made from refractory bricks, similar to those used in the miniature furnace. A ceramic kiln shelf painted with a glass kiln wash of 50% Kaolin, 25% Alumina Hydrate and 25% silica was placed on three props on top of the refractory bricks. Fibre paper was used on top of the kiln wash to protect the kiln shelf from any glass spills. The lid of the kiln was lined with ceramic fibre on all the sides and top. Ceramic buttons had been made to hold the fibre in position. Electrical elements made from coils of Nichrome wire (approximately 80% nickel and 20% chromium suitable for temperature up to about 1100 degree Celsius) were laid into the top of the lid of the flat-bed kiln in four rows and an entry hole for an electric pyrometer was placed in the centre. This pyrometer was attached to a HARCO digital display computer for controlled firing of the flat-bed kiln. This flat-bed kiln fires up to a temperature of 1000 degrees Celsius.

**Figure 2.** Designing the equipment.

*Custom-made Flat bed kiln.*



*My Flat-bed/Annealing kiln used for bead-making and other experiments.*

<b><i>Exterior measurements</i></b>	<b><i>Electricity volts: 240</i></b>
<i>Width: 86 cms Length: 68 cms Depth (Height: 38 cms.</i>	<b><i>Phase: 1 Amps: 15</i></b>
<b><i>Interior measurements</i></b>	<b><i>KW Rating: 3.6</i></b>
<i>Width: 72 cms Length: 52 cms Depth(Height: 32 cms)</i>	<b><i>Maximum temperature: 1000 degrees Celsius</i></b>

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## **Appendix Ai (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice.**

This appendix supplements Chapter Two and contains the historical details of the International Contemporary Studio Glass Movement and the Contemporary Studio Glass Movement which had its origins in postwar Europe.

The glass factories in Italy and Scandinavia influenced American artists. Central to the development of the movement were the workshops for artists and technicians that were sponsored by the Toledo Museum of Fine Arts in Ohio. Harvey Littleton, a ceramic artist and designer, son of former Director of Research at Corning Glass Works, questioned whether it was possible to melt glass in the private glass studios and initiated what became the contemporary studio art glass movement in the early 1960s.

Workshops for artists and technicians were sponsored by the Toledo Museum of Fine Arts in Ohio. Littleton dreamed of finding a way for an individual artist to work directly with glass outside of the factory setting, after his travels to the Venetian island of Murano in Italy. Glass technician Dominick Labino and other artists interested in studio glass attended a workshop held by Littleton in Toledo. Littleton had organized a workshop where a primitive home-made pot furnace was used to melt glass. The results were promising despite the fact that the molten glass did not perform to their expectations. They continued to experiment with the technicalities of melting glass and devised a new simple style of glass furnace. The purpose of redesigning the furnace was to bring the new medium of creative studio glass to individual artists. Glass, as an industrial material, had not been challenged until 1962 when Harvey Littleton questioned if it were possible to melt glass in different ways. After much experimentation and two seminars held in Toledo, a class of creative glass blowing was introduced by Littleton at the University of Wisconsin at Madison where he was teaching. By 1964, Littleton was appointed chairman of the Art Department at the University of Wisconsin where he established an undergraduate glass course, the first of its kind in the United States of America. Marvin Lipofsky, the first graduate student, was hired to start a glass programme at the University of Berkeley, California. Since the 1950s a group of Californian potters led by Peter Voulkos at the University of California had been applying some of the principles of Abstract Expressionism Art to their clay work. Their sculptural work apparently had an influence on the work of the studio glass artists. Art schools became pivotal for the development of contemporary art-glass as artists moved away from

working in factories.

Edwards (1998, 182) stated that studio glass since the 1960s has become one of the most dynamic and innovative of all the contemporary art-craft streams, whether for functional or artistic purposes. Because the United States had very short glass history American glass artists travelled to National and International conferences and exhibitions and the result was that many friendships were formed during this time. In 1967 Dale Chihuly, another of Littleton's students, visited the World Expo in Montreal. Here he met Stanislav Libensky and Jaroslava Brychtova, from Czechoslovakia. Chihuly's exposure to the Czech tradition of monumental glass casting showed him another way of creating art. Previously, the emphasis had been placed on blown glass, technique had not been important. Littleton and his early students had been committed to the idea of establishing a direct relationship with glass in ways that had never previously been explored. Chihuly founded the Pilchuck School near Seattle in 1971. It was at Pilchuck where an important exchange of ideas had a marked influence on glass internationally, as world wide renowned glass practitioners held master-classes.

Throughout the 1970s and 1980s better materials and more sophisticated equipment generated more interesting work. Exciting new possibilities in the medium started to emerge and traditional glass disciplines were transformed. The American Contemporary Studio Glass Movement inspired European, Japanese and Australian glass artists to look at their own work areas and they were encouraged to move away from the factory work environment (Leier, Peters and Wallace 2000). Glass education was well developed in most countries by the beginning of the 1990s. Various Australians returning home from trips overseas as well as established artists from Britain and the United States introduced new ideas in contemporary glass to Australia. In 1983 Klaus Moje arrived in Australia from Germany to teach at the Canberra School of Art, a part of the Australian National University. He established what is now regarded as one of the most sophisticated university glass departments. Today, making glass is internationally accepted as a legitimate medium for artistic expression. Artists using glass are able to express the full range of human emotion, in sculptural form and in vessel form.

It can be argued that inspired teaching has been at the heart of the contemporary glass movement. The handing on of information in an university environment has been the single most important factor in the changes that have taken place in glass. These changes were due to a group of well-known international glass artists such as Stanislaus Libensky and Jaroslava Brychtova of the Czech Republic, Dale Chihuly of the United States, Lino Tagliapietra of Italy and Bertil Valien of Sweden. It was their commitment to the medium that changed the role of glass in the art world and encouraged other artists and designers to broaden their horizons. Chihuly, Libensky, Brychtova were an inspiration to their students because of the way they transformed traditional glass production. A whole new artistic language with its own grammar and technical vocabulary

was established in most areas of glassmaking by the beginning of the 1990s (Klein 2001, 262).

### **Industrial Studio Glass**

Before the spread of the International Studio Glass movement in the early 1960s there were distinct national styles. Countries competed with one another at World Fairs in a nationalistic spirit. Lately, the art of the individual has become the focus so it is much less easy to identify a new piece of glass by its national characteristics. The Italians, above all colourists, have been innovative and very active but the volume of output produced by the Scandinavians, who were the most inventive in terms of technique, gave them an edge. In Czechoslovakia, there was a flourishing glass industry but it developed in comparative isolation. In some aspects, such as glass sculpture, however, Czechoslovakian glass was a head of its time (Klein & Ward 1993, 248).

### **Designers**

From a global perspective, glass blowing appears to have developed in two distinct modes: mostly, emphasis has been given to technological improvement and only in isolated cases has artistry been the driving force.

Klein and Ward (1993, 246) state that except in Britain, most of the major glassworks had a studio department, where glass was produced by a team of workers, in which each member had a clearly defined role. Except in rare cases, glass was designed on paper and executed by a team of expert craftsmen. The oldest traditions of glass making were continued in this environment.

Scandinavian designers were able to achieve such variety because they had access to highly trained craftsmen specializing in the different skills of the glass trade. This is an advantage because an individual glass worker rarely masters more than a couple of skills, for example, the master blower seldom also becomes a master engraver. Teamwork is a special characteristic of the Swedish glass industry in that it takes time for collaboration to produce results and this leads to the development of a successful studio tradition.

Norwegian and Danish glass have many similarities: Design is much more closely related to function than in the case of Swedish glass. The Finnish glass industry had some of the most outstanding glass artists of this period. Italian glass on the other hand has a very different appeal, based on spontaneity, freshness and an elusive elegance. Italian shapes depend on hot glass

techniques such as blowing, almost to the exclusion of the cold techniques of cutting and engraving. The city of Venice remains at the heart of the Italian glass industry, with a long history of glass blowing unparalleled anywhere else in the world. The art of the Venetian glass blower dominates Italian glass artistry and design and essentially all new techniques and new design, whether Free blown or mould blown, revolved around this particular skill (Klein & Ward 1993, 251).

Before the Second World War, Daum and Lalique were the dominant influences in the French glass industry. Their style was more traditional than the concepts being developed in Czechoslovakia. Italy and Scandinavia had been the undisputed leaders of the modern movement in glass. Other countries exhibiting at World Fairs included the products of Belgium, where the style remained derivative. Dutch glass, continued to be avant-garde whereas in Germany, glass manufacturers with a few notable exceptions were concerned mainly with industrial needs. In Britain, apart from a few isolated individuals, there was very little activity in artistic glass in the immediate post-war years similarly in the United States of America, there were few developments outside the research programmes on glass technology and glass chemistry. In the Far East, only two Japanese glass works make art glass in the western tradition: most of the glass produced is either mould blown or pressed in clear or frosted glass. In contrast, Japanese output demonstrates a consistently high level of technical achievement (Klein & Ward 1993, 258).

### **Post Studio Art Glass movement**

Klein and Ward (1993, 265) also mention that since the 1960s, art glass has moved away from this industrial environment. Both glass technology and glass artistry is now taught at university level. Previously glass artisans learned their trade in the industry and the designers and artists mostly came to glass by a roundabout route. A more intellectual attitude has been taken in recent years towards glass art and this has given modern glass artists a new status. Glass art has become accepted as a serious art form. Glass-making techniques such as *pate de verre*, kiln casting, lost-wax casting, electroforming, lamp work, sand-casting, engraving, optical cutting, enamel-painting and fusing have been re-invented argues Klein (2001). This is due to better equipment and artistic imagination. New ideas have emerged, such as Mary Ann Toots Zynsky's technique of working with glass threads and Mary Van Cline's use of photographs printed into photosensitive glass.

### **References**

## **Appendix Bi (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study experiments:

#### **Scoping Case Study One: Pulling and drawing molten glass (hot glass). Sub-category: 5.0.1 Stringers**

##### **Overview of sub-category 5.0.1: Stringers**

Stringers are often referred to as ribbon glass. Ribbon glass is glass that has been pulled (like toffee) when still hot. The pulled stringers or ribbon glass threads were often fused together to make a sheet of glass then this sheet was placed over a bowl-shaped mould and heated so that the sheet would slump over the mould (Bray, 2001, 65).

##### **Scoping case study project aims**

This case study's aims for sub-category 5.0.1 were to research how to incorporate photosensitive glass into the traditional hot glass technique of pulling and drawing by using as many innovative methods as possible, so as to provide new opportunities to produce a novel way for glass artists/photographers.

##### **Detailed questions to be asked by myself the investigator**

Prompts concerning the information that has to be gathered by the investigator

- In what ways could I prepare the photosensitive glass for incorporation into the hot glass pulling technique?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was making stringers, canes or rods?

- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before I pulled it to make stringers?
- What would happen if I rolled my gather of furnace glass on a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before pulling the mixture?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before pulling the mixture?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before pulling it?
- How would I cut up the pulled photosensitive glass stringers, canes or rods what tools would I need?
- How would I safely store the pulled photosensitive glass experiments before to exposing them to ultra violet light?
- What annealing requirements are there for pulled photosensitive glass?
- List of sources of evidence that cover observations by the investigator.
- Classification,
- Observation
- Description of sequences and consequences (Lubbe 2003).

### **Scoping Experiment A**

Sub category 5.0.1: Pulling the photosensitive stringers.

#### **Process/activity:**

Using the traditional method (under red-photographic light), a half a rod of photosensitive glass was cut up into small disk-like sections with a diameter of 250 mm and the thickness of 50 mm. They were then placed into an annealing kiln to heat up to 565 degrees Celsius before being picked up on the end of a punty. The photosensitive glass disk at the end of the punty was then heated up in the glory hole and rounded into a ball at the end of the punty before the glass

blower plunged it into the molten glass inside the furnace so as to gather some clear soda lime furnace glass around the photosensitive ball of glass. The hot ball of molten glass was then marvered in to a shape resembling a light bulb before heating it up once more in the glory-hole. The collaborating artist or assistant got another punty ready with a cookie at the end of her punty. Once the bulb of hot molten glass was under control the glass blower attached the bulb to the cookie. At this stage the pulling of the glass attached to the two punties commenced. This pulling was done slowly allowing the glass to cool down to the size required for the stringer, cane or rod of glass. This action was similar to pulling toffee. The stringer was then cooled by placing it onto the clean floor and broken up into 30 mm lengths before putting it away in a dark room. This same process applies to canes and rods. Once the stringer canes and rods are cool they must be stored in a light-proof wrapping of black plastic and then stored in a light proof container until needed for use.

Ultra violet light time related exposure tests were made by blocking off sections of the stringer or cane using black electrical tape using the subtractive photographic exposure method. Intervals of time selected for the ultra violet light exposures were for five, ten, fifteen, twenty, twenty five and thirty minutes. Scoping heat development tests were then carried out on the ultra violet light exposed stringer or cane in a digitally controlled electric kiln at a certain temperature for a certain length of time. Ultraviolet light exposure was from 60, 80, 100, 120 and 140 minutes at a heat development temperature of 550 degrees Celsius. Development times were for 271 minutes.

## **Figure 1: Scoping Experiment A**

Sub category 5.0.1: Pulling the photosensitive stringers.



## **Scoping Experiment B**

**Sub category 5.0.1: Pulling the photosensitive stringers.**

Innovative method: Process/activity

### **Stage One:**

(Under red photographic light) One hundred millimeters of photosensitive glass rod was used to make up some crushed glass ranging from a fine powder to a coarse brown coffee sugar consistency. The crushed glass was stored in light proof containers. When the various crushed photosensitive glass was needed it was put into a shallow stainless steel container and covered with a black light proof plastic sheet.

### **Stage Two:**

The glass artist gathers molten glass from the furnace then marvers it into a shape resembling a light bulb. The light bulb shape is then heated up again in the glory hole before the glass artist dips and rolls the light bulb end of hot glass in the crushed glass. The artist returns the rod to the glory hole to heat up the crushed photosensitive glass on the light bulb and melts it into the body of the hot glass. This process is then repeated, the glass artist picking up the

crushed photosensitive glass as many times as required and returning to the glory hole to melt the crush into the body of hot glass. At this stage the glass artist may wish to add a variable of crushed colour such as white into the glass before returning to the furnace to gather more glass on the rod. Then the glass artist marvers the light bulb shape into a square or triangle ready for pulling. Square canes and square stringers are often used in art glass ware.

The collaborating artist gets the cookie ready on a punty. When the glass artist has the light bulb shaped molten glass at the end of the blowing iron hot enough and under control it can be attached to the 'cookie' and the pulling process and be started.

**Variation:**

A light background of glass can gathered from the furnace before picking up crushed photosensitive glass for pulling the stringer, rod or cane.

**Stage Three**

Annealing was not necessary because of the thinness of the stringers (Graham Stone 1999 & 2000). They were wrapped up in light-proof containers and placed in storage in a dark cupboard until ready for ultraviolet light exposure and heat development.

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## **Appendix Bi (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study One: Pulling and drawing hot glass.**

##### **Sub-category:5.0.2 Murrine or Mosaics**

##### **Overview of sub-category 5.0.2.Murrine**

Murrine are canes of pulled glass made up with layers of colours, fused together then pulled. When cool they are then cut up into sections. These small sections are often referred to as mosaic canes. They are often fused together before being slumped into/or over a bowl shape. Murrine is an ancient decorative technique used by the Romans and refined by the Venetians. This activity involves working with molten (hot glass) and with glass at room temperature (cold glass) (Kerkvliet 1997).

##### **Scoping Case study project aims**

The aims of this scoping case study for sub-category 5.0.2. were to research through experimentation how to incorporate photosensitive into the tradition technique of making murrine.

##### **Detailed questions to be asked by myself, the investigator**

Prompts concerning the information that has to be gathered by the investigator.

- In what ways could I prepare the photosensitive glass for incorporation into the hot glass pulling technique for murrine?

- How could I apply the made photosensitive glass murrine to a blown art piece?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was making murrine?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before I pulled it to make murrine?
- What would happen if I rolled my gather of furnace glass using a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before pulling the mixture to make murrine?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before pulling the mixture to make murrine?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before pulling it to make murrine?
- How would I cut up the pulled photosensitive glass to make murrine?
- How would I safely store the pulled photosensitive glass murrine experiments before exposing them to ultra violet light?
- What annealing requirements are there for photosensitive glass murrine?

**Process:** (standard applications) **and technical skills required:** 5.0.2: making murrine.

It is a fairly simple activity, like pulling hot toffee then cutting the cane or stringer up into short lengths. Making murrine does not require blowing expertise however, access to a hot glass furnace is necessary. The Corning Museum of Glass ([cmog.org](http://cmog.org) 2007) and Corning Museum of Glass – [youtube.com](http://youtube.com) publish videos that demonstrate a variety of techniques for making murrine and mosaic glass by working glass artists. Various art-glass making members of Glass Bulletin Boards discuss and illustrate the techniques for making murrine and mosaics.

Dinah Hulet (2004) writes that the techniques that she uses in all of her work with mosaic glass are combinations of the three variations of the traditional techniques; the “cold” method of arranging pre-made coloured rods or threads of glass vertically so that they create an intricate design which would then be bundled together, held with wire, heated, fused and drawn out into a length of bar or cane. The “hot” method, where gathers of molten glass of different colours would be tooled and shaped into the intended design and then stretched to length as in the Giacomo Franchini variation of the “hot” method. Hulet (2004) describes how she extensively prepares the component parts which are made using the flame of an oxygen and propane fueled torch as her initial heat source.

*“Not all of these component parts are then fused together in the flame, though most are. Not all of these component parts are stretched into cane, though some are. Very, very few of these components parts are used in more than a single image. The one constant element that exists in all of my work with mosaic glass is the concept of an image being made up of and contained within the glass itself. By creating the design (in my work, most often portraiture) inside the glass rather than placing it on the surface, as with painting or enamelling on glass, the imagery takes on the fluid characteristics of the molten glass from which it is made. Through the use of the mosaic glass techniques I am able to translate into visual form the imagery that fascinates me. And it is the imagery that is my focus – with technique as my tool”* (Hulet, D. 2004).

### **5.0.2 Scoping experiments.**

After building my miniature furnace at the School of Art, Curtin University, Bentley, Perth, Western Australia Murrine scoping experiments commenced.

#### **5.0.2a. Scoping Experiment A.**

Murrine using hot#101 Opal White glass rolled in crushed photosensitive glass chips with a gather of hot furnace glass over the chips. This scoping experiment was unsuccessful.

**5.0.2b. Scoping Experiment B.** Murrine using crushed photosensitive glass and hot furnace glass. This scoping experiment was unsuccessful.

#### **5.0.2c: Scoping Experiment C. Photosensitive glass Murrine.**

**Figure 1.**



1. UV exposure for 80 minutes.  
Heat development @ 550 deg. Celsius for  
271 minutes.



2. UV exposure for 80 minutes.  
Heat development @ 600 deg. Celsius  
For 271 minutes.



3. UV exposure for 80 minutes.  
Heat development @ 655 deg. Celsius  
for 271 minutes.



4. UV exposure for 80 minutes.  
Heat development @ 700 deg. Celsius  
for 271 minutes.

### **5.0.2c:Scoping Experiment C.**

#### **Pulling the photosensitive stringers to make murrine.**

##### **Process/activity:**

Using the traditional method (Under red-photographic light), a half a rod of photosensitive glass was cut up into small disk-like sections with a diameter of 250 mm and the thickness of 50 mm. They were then placed into an annealing kiln to heat up to 565 degrees Celsius before being picked up on the end of a punty. The photosensitive glass disk at the end of the punty was then heated up in the glory hole and rounded into a ball at the end of the punty before the glass blower plunged it into the molten glass inside the furnace so as to gather some clear soda lime furnace glass around the photosensitive ball of glass.

The glass artist gathered molten glass from the furnace then marvered it into a shape resembling a light bulb. The light bulb shape was then heated up again in the glory hole before the glass artist dipped and rolled the light bulb end of hot glass in the crushed glass. The artist returned the rod to the glory hole to heat up the crushed photosensitive glass on the light bulb and melted it into the body of the hot glass. This process was then repeated, the glass artist picking up the crushed photosensitive glass as many times as required and returning to the glory hole to melt the crush into the body of hot glass. At this stage the glass artist may wish to add a variable crushed colour such as white into the glass before returning to the furnace to gather more glass on the rod. Then the glass artist marvered the light bulb shape into a square or triangle ready for pulling.

The collaborating artist or assistant got another punty ready with a cookie at the end of her punty. Once the bulb of hot molten glass was under control the glass blower attached the bulb to the cookie. At this stage the pulling of the glass on the two punties started. This was done slowly allowing the glass to cool down to the size required for the stringer, cane or rod of glass. This action was similar to pulling toffee. The stringer was then cooled by placing it onto the clean floor and broken up into 30 mm lengths before putting it away in a dark room. This same process applied to cane and rods. Once the stringer

canes and rods are cool they must be stored in a light-proof wrapping of black plastic and then stored in a light proof container until needed for cutting up into short length for murrine. Square canes and square stringers are often used in art glass ware.

**Variation.**

A light background colour of glass can gathered from the furnace before picking up crushed photosensitive glass for pulling the stringer, rod or cane with a view to making murrine.

Four separate groups of clear photosensitive glass canes were cut up into small lengths using a pair of pliers. They were then placed alongside one another, standing upright before exposing them to ultraviolet light for eighty minutes. This exposure time was based on the scoping experiments made on the group of stringers and canes that were pulled in sub category 1. Each group of ultra violet light exposed murrine was then heat developed in an electric kiln at different temperatures but for the same length of time as the canes and stringers.

**Result:**

This scoping experiment was successful.

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## **Appendix Bi (c)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study One: Pulling and drawing hot glass**

##### **Sub-category 5.0.3: Pouring medallions or cutting rods for Crowns and/or Bullions**

#### **Overview of sub-category 5.0.3.Crowns and/or Bullions**

Crowns or Bullions were the major source of sheet glass for many centuries. Small panes of glass were cut out from the crowns. Because Crown and/or Bullions were made directly from blown and spun glass, they were much more brilliant than the other forms of sheet glass which were available (Bray 2001, 202).

#### **Scoping Case study project aims**

The aims were to research how to incorporate photosensitive glass into this traditional technique by using as many innovative methods as possible so as to provide new opportunities to produce a novel way for architectural use by glass artists and photographers.

#### **Detailed questions to be asked by myself, the investigator**

Prompts concerning the information that has to be gathered by me the investigator

- In what ways could I prepare the photosensitive glass for incorporation into the hot glass Crowns or Bullions technique?

- What would happen if I used re-cycled crushed photosensitive chips or powder when I was making Crowns or Bullions?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before making Crowns or Bullions?
- What would happen if I rolled my gather of furnace glass on a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before making Crowns or Bullions?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before making Crowns or Bullions.
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before making Crowns or Bullions?
- How would I cut up the photosensitive glass Crowns or Bullions and what tools would I need?
- How would I safely store the pulled photosensitive glass experiments before to exposing them to ultra violet light?
- What annealing requirements are there for Crowns or Bullions in photosensitive glass?
- List of sources of evidence that cover observations by the investigator.
- Classification,
- Observation,
- Description of sequences and consequences (Lubbe 2003).

**Process (standard applications) and technical skills required: sub-category**

### **5.0.3. Pouring medallions or cutting rods for Crowns and/or Bullions**

#### **Process for producing a Crown or Bullion**

Gathering molten glass on the end of a blowing rod is the first step taken by the glass blower. This gather of molten glass has to be repeatedly dipped into molten glass to gather sufficient glass to make a large enough crown, 5 kilos is

the estimated weight. The glass is blown into a pear shape and repeatedly heated in the glory-hole between blowing to enlarge it. While the glass is still hot and soft, the side opposite the blow pipe is partially flattened placing the pear-shaped on to a very smooth metal table. A punty (pontil) a solid iron rod, with a small gather of molten glass on its end is applied to the flattened side of the pear shape blown piece then the glass blower removes the blowing pipe by using 'Jacks' and water. This process of detaching the piece from the blowing pipe leaves a circular hole. The punty (pontil) now holds the piece which is re-heated in the glory hole and spun. The hole slowly enlarges as the globe is repeatedly heated in the glory hole and spun until the 'hole' is the same diameter as the disc and at this point, further spinning caused the hole to vanish, leaving a uniform disc about 125 to 150centimetres (50-60 inches) in diameter. The disc will be of uniform thickness, except at the point where it connects to the punty. This point is called the bull's eye. The disc is detached from the punty and is placed in the annealing kiln to remove brittleness so as to allow the disc to be cut as required.

### **Process for making Cylinder flat glass**

The only traditional method of flat glass-making that remains is the cylinder process, also known as broad or sheet glass. The glass is gathered on to the end of the blow pipe and placed on a block of wood hollowed out to the diameter required, and is then blown to the required dimensions. The glass is then reheated in a kiln. When the glass is ready the glass blower swings the pipe in a vertical plane and inflates the glass until it is elongated into a cylinder of the required dimensions. Next a lump of molten glass is attached then the cylinder is blown until the heated part allows it to open. The cylinder is then re-heated and opened out by rotation. It is next laid on a wooden horse and detached from the pipe by the application of a cold iron. It is then split down the length by cutting or the use of a hot iron. The split cylinder is then passed into the flattening chamber of the kiln, re-heated and flattened on a smooth stone with the use of a "polissoir" or block of wood on the end of a rod. It is then passed

into the annealing chamber of the kiln. Making cylinder glass may vary slightly from country to country. At present there are three factories left in Europe and one in the USA. The process has survived because there is still a demand for this type of glass. The colour range is limitless; the glass is used in churches, commercially, domestically and for restoration purposes. It is also easier to make in comparison to any of the other processes. The process was resurrected briefly in 1998 at the National Glass Centre in Sunderland, but despite having had a lot of publicity and aid from various sources, it closed in 1999. Production on a smaller scale was planned to re-commence in 2006.

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## **Appendix Bii (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study Two: Crushing and recycling (warm glass).**

##### **Sub-category 5.2.1:Chunk de Verre.**

##### **Overview of sub-category: Chunk de Verre**

Chunk de Verre is that name that I have given to large chips of recycled photosensitive glass collected from the recycling bin in the glass studio. These large chips of glass are fused together in an electric kiln. The technique is similar to that of Pate de Verre.

##### **Scoping Case study project aims**

Assorted chips of photosensitive glass off the moyle (a section of a glass blower's blowing pipe) were collected for the purpose of determining whether it was possible to recycle blown photosensitive glass.

##### **Detailed questions to be asked by myself the investigator**

Prompts concerning the information that has to be gathered by the investigator.

- What methods can I apply to incorporate photosensitive glass into the technique of Chunk de Verre (medium to large chips of glass off the moyle)?
- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was making Chunk de Vere?

- What would occur if I used unfired, chips of crushed photosensitive glass then fired them to a selected temperature after exposing them to ultraviolet light?
- What would the result be if I pre-flamed a large chip of photosensitive glass in the glory hole on a punty then dipping it into the molten furnace glass before crushing the mixture?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping them into the furnace glass then crushing them when they had cooled?
- How would I store the crushed recycled photosensitive glass?
- What annealing requirements are there for photosensitive Chunk de Verre glass?

**Process (standard applications) and technical skills required for Chunk de Verre**

The pieces of shattered photosensitive glass from the moyle of the blowing pipe were saved and placed in a tin with a lid so as to keep the light out.

Selection according to the size of the shatter piece of photosensitive glass for the Chunk de Verre scoping experiment was then made. The smaller pieces of shattered glass were set aside and saved in a separate light proof container for Pate de Verre scoping experiments.

- 

What I set out to do:

- Save the pieces of shattered photosensitive glass from the moyle of the blowing pipe and place them in a tin with a lid so as to keep the light out.
- Crush the required amount of the shattered pieces of photosensitive glass to use in the Pate de Verre experiment.
- Select according to size the remainder of the shattered pieces of photosensitive glass for the chunk de verre experiment.

- Keep all the selected photosensitive glass in lightproof containers or black photographic bags until ready for use.
- Record the orientation of the ultraviolet light tubes situated in the top of the light-box.
- Select an exposure time range for the experiments for example 40 minutes to 120 minutes for ultraviolet light exposure.
- Select a temperature range for the heat development of the latent ultraviolet exposed photosensitive Pate de Verre experiments. For example 525 degrees Celsius, 550 degrees Celsius, 575 degrees Celsius 600 degrees Celsius and 650 degrees Celsius.
- The orientation of the two ultraviolet light tubes in the top of the ultraviolet light exposure box was recorded on paper.
- Write out a kiln-firing program to record the experiment results.

What I used:

- Assorted sizes of recycled chips of photosensitive glass off the moyle.
  - Ultraviolet light box
  - Digital timer
  - Turntable/ [rotating/non-rotating] Venco Pottery wheel.
  - HARCO digital controller.
  - Electric kiln for testing

### **Scoping experiments: Colour Saturation**

The pieces of shattered photosensitive glass from the moyle of the blowing pipe were saved and placed in a tin with a lid so as to keep the latent ultraviolet light out. Selection according to size the remainder of the shattered pieces of photosensitive glass for the chunk de verre experiment then made. All the selected photosensitive glass in lightproof containers or black photographic bags until ready for use was made.

### **Ultraviolet light exposure and heat development**

The orientation of the ultraviolet light tubes situated in the top of the light-box was recorded on paper then an exposure time range for the experiments for example 40 minutes to 120 minutes for ultraviolet light exposure was selected. A temperature range for the heat development of the recycled photosensitive chunks of glass such as 525 degrees Celsius, 550 degrees Celsius, 575 degrees Celsius 600 degrees Celsius was chosen. A kiln firing program was written out for each selected temperature to record the experimental results.

**5.2.1a. Scoping Experiment A. Figure 2.** [rotating turntable] under red light/safe light conditions.

#### **Method:**

Crushed photosensitive glass chips suitable for Chunk de Verre were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery bat, secured to the pottery wheel-head. Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The photosensitive glass chips were exposed for 101 minutes under ultraviolet light. The nine exposed cup cake chips were then placed into an electric kiln for heat development @ 550 degrees Celsius for 271 minutes.

**Figure 1.**



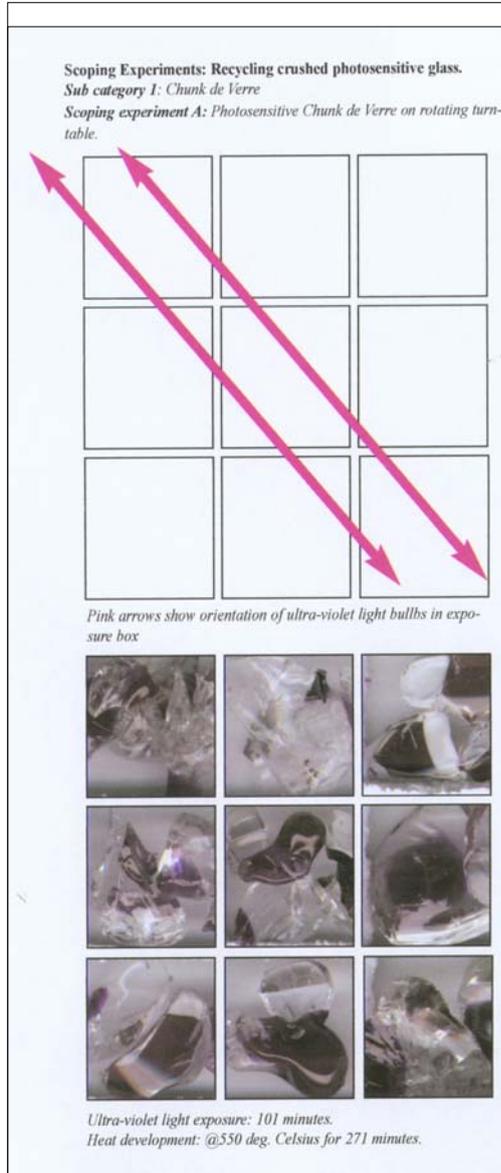
**5.2.1b Scoping Experiment B. Figure 3.** [Static turntable] under red light conditions.

**Method:**

Crushed photosensitive glass chips suitable for Chunk de Verre were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery bat, secured to the pottery wheel-head. Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The photosensitive glass chips were exposed for 101 minutes under ultraviolet light. The nine exposed cup cake chips were then placed into an electric kiln for heat development @ 550 degrees Celsius for 271 minutes. The results were scanned using a UMAX Powerlock Scanner and printed.

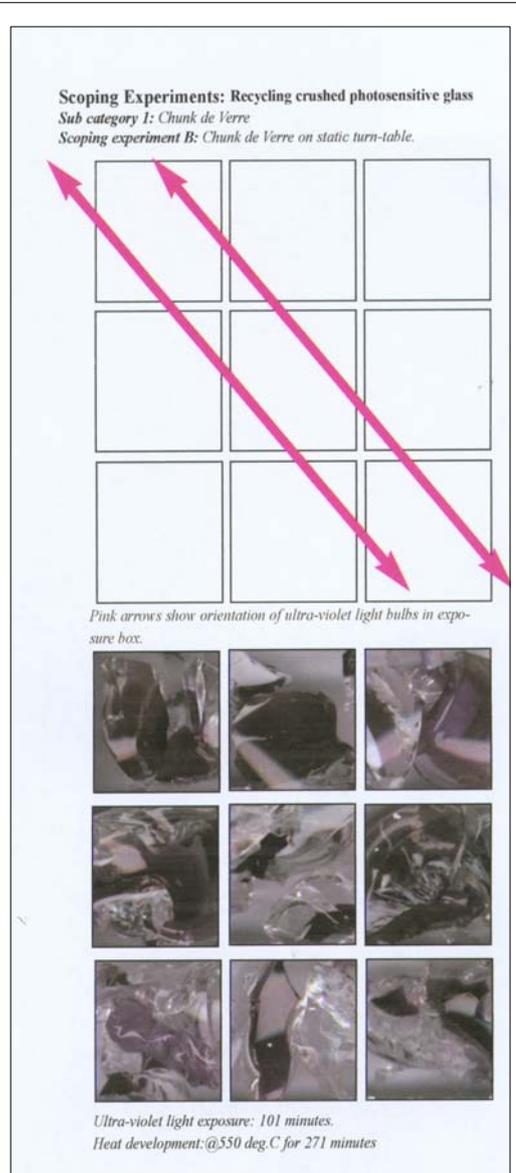
**Figure 2.**

Shows results from a rotating turntable.



**Figure 3.**

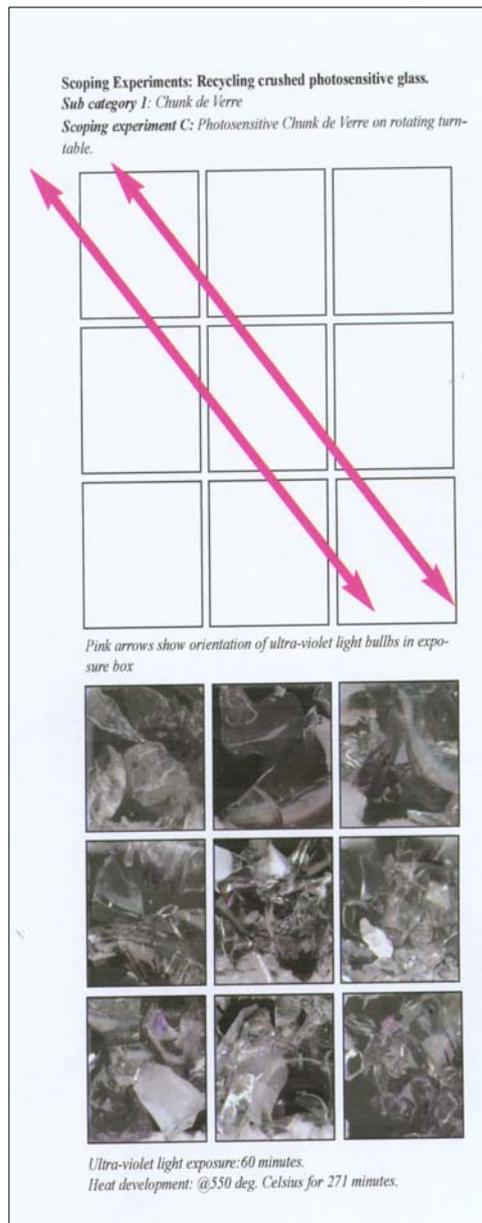
Figure 3 shows results from a static turntable.



There was no difference in colour in each of the nine boxes in both experiments after being exposed to ultraviolet light on a rotating and a static turntable. These results were due to the high temperature of 550 degrees Celsius during heat development.

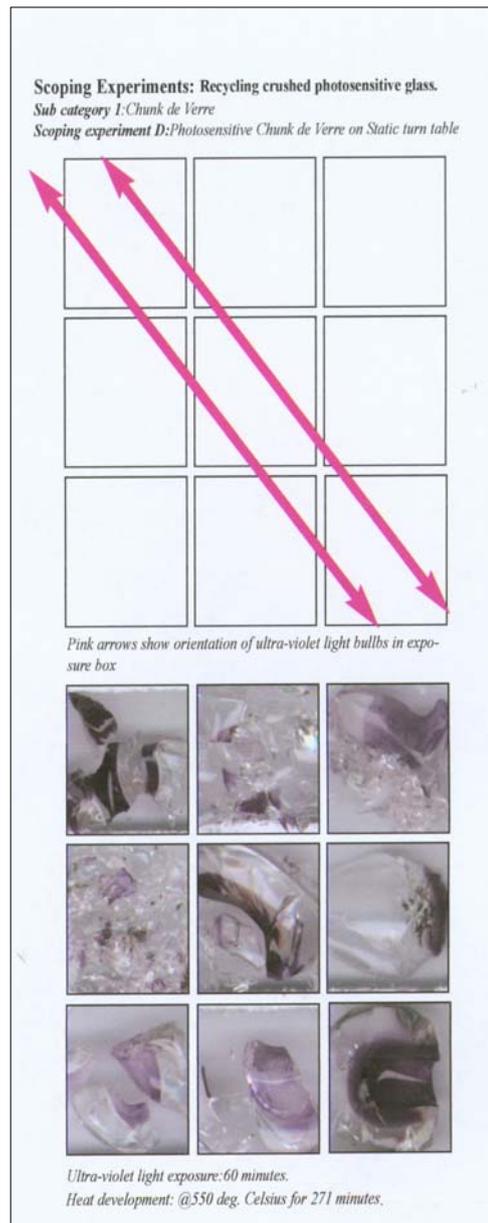
**Figure 4.**

Shows results from a rotating turntable.  
No difference in colour can be seen in the nine boxes of this experiment.



**Figure 5.**

Shows results from a static turntable. Note that boxes 1, 5 and 9 are darker in colour than the other boxes.



**Hypothesis applicable to sub-category 5.2.2.Chunk de Verre.**

Crushing and recycling photosensitive glass. It is postulated that the positioning of a scoping experiment under the two ultraviolet light tubes situated in the top of the light-box should give different colour density results when placed on a rotating turntable compared with the results from a non-rotating turntable. In addition it is postulated there is a relationship between the exposure times of the crushed recycled photosensitive glass chunks under controlled ultraviolet light conditions and the development temperatures under timed digital control in an electric kiln. Colour variations could be designed for exact placement on a prototype using a non rotating turntable under ultraviolet light whereas uniform colour exposure design should result from the rotating turntable.

**5.2.1c Scoping Experiment C. Figure 4.** [Rotating turntable] under red light conditions

**Method:**

Crushed photosensitive glass chips suitable for Chunk de Verre were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery bat, secured to the pottery wheel head. Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The photosensitive glass chips were exposed for 60 minutes under ultraviolet light. The nine exposed cup cake chips were then placed into an electric kiln for heat development @ 550 degrees Celsius for 271 minutes.

**Process (Standard applications) and technical skills required.**

**5.2.1d. Scoping Experiment D. Figure 5.** [Static turntable] under red light conditions.

**Method:**

Crushed photosensitive glass chips suitable for Chunk de Verre were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery 'bat', secured to the pottery wheel head. Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The photosensitive glass chips were exposed for 60 minutes under ultraviolet light. The nine exposed cup cake chips were then placed into an electric kiln for heat development @ 550 degrees Celsius for 271 minutes.

**Results:**

Comparisons between static and rotating turntable results to show relative values were made and it was observed that Scoping Experiment A and Scoping Experiment B that were exposed to ultraviolet light on rotating and static turntables for 101 minutes then heat developed in a HARCO Digitally controlled electric kiln @ 550 degrees Celsius for 271 minutes did not show any difference between a static and a rotating turntable ultra violet light exposure for 101 minutes. However, Scoping Experiment D's crushed photosensitive Chunk de Verre glass chips that were exposed for 60 minutes and heat developed at 550 degrees Celsius for 271 minutes on a static turn table had darker results at numbers 1, 5 and 9 scanned printouts than Scoping Experiment C's chips that was exposed to ultraviolet light for 60 minutes under a rotating turntable then heat developed for the same temperature and time.

**Figure 6.**



### **5.2.1e. Scoping Experiment E. (the control) Figure 6.**

This figure shows a comparison between photosensitive chunk de Verre Chips made using clear soda lime glass and (the variable) Opal white glass used in addition with the photosensitive glass chips exposed under ultraviolet light for 90 minutes, 100 minutes and 110 minutes on a static turntable then heat developed @ 600 degrees Celsius for 271 minutes.

#### **Results:**

The results of the comparison between the control and the variable in Scoping Experiment D show that in the experimental variable, the range of colours is broader than in the control.

#### **Conclusion:**

The results indicated that further experiment involving shorter ultra violet light exposures on a static turn table, then heat developed at lower temperatures for a shorter length of time would give similar results to the experiment that was heat developed at 550 degrees Celsius and ultra violet light exposed for 60 minutes on a static turn table. Possible improvements in techniques used were considered and at this stage the author decided that Line blending and/or Triaxial blending of crushed photosensitive glass pieces may give far more controlled and informative results.

#### **My objectives.**

The objective of these scoping experiments was to determine if there would be any difference in colour saturation results of the recycled photosensitive glass taken off the moyle (blowing pipe) when exposed to ultraviolet light using a non-rotating turntable compared with a rotating turntable after heat development in an electric kiln using a HARCO controller.

The second purpose of these experiments was to determining the timing of ultraviolet light exposures most likely to give the optimum exposure results when using a rotating turntable or a static turntable

The second objective was to determine the optimum heat development temperature required to develop that latent ultraviolet light exposed image using crushed recycled photosensitive glass off the moyle.



## **Appendix Bii (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Two: Crushing and recycling (warm glass) Sub-category 5.2.2. Pate de Verre**

##### **Overview of sub-category 5.2.2: Pate de Verre**

This activity involves working with molten (hot glass) and with glass at room temperature (cold glass) (Kerkvliet 1997).

##### **Scoping Case study project aims.**

This scoping case study's aims for sub-category 5.2.3 were to research through experimentation how to incorporate photosensitive into the tradition technique of making Pate de Verre.

**Detailed questions to be asked by myself**, the investigator were similar to those asked when doing scoping experiments on Chunk de Verre.

##### **Process (standard applications) and technical skills required for Pate de Verre**

##### **Crushed photosensitive glass scoping Pate de Verre experiment**

The pieces of shattered photosensitive glass from the moyle of the blowing pipe were saved and placed in a tin with a lid so as to keep the light out.

**What I set out to do:**

- Save the pieces of shattered photosensitive glass from the mangle of the blowing pipe and place them in a tin with a lid so as to keep the light out.
- Crush the required amount of the shattered pieces of photosensitive glass to use in the Pate de Verre experiment.
- Select according to size the remainder of the shattered pieces of photosensitive glass for the chunk de verre experiment.
- Keep all the selected photosensitive glass in lightproof containers or black photographic bags until ready for use.
- Record the orientation of the ultraviolet light tubes situated in the top of the light-box.
- Select an exposure time range for the experiments for example 40 minutes to 120 minutes for ultraviolet light exposure.
- Select a temperature range for the heat development of the latent ultraviolet exposed photosensitive Pate de Verre experiments. For example 525 degrees Celsius, 550 degrees Celsius, 575 degrees Celsius 600 degrees Celsius and 650 degrees Celsius.
- The orientation of the two ultraviolet light tubes in the top of the ultraviolet light exposure box was recorded on paper.

**Ultra violet light exposure and heat development.**

The orientation of the ultraviolet light tubes situated in the top of the light-box was recorded on paper then an exposure time range for the experiments for example 40 minutes to 120 minutes for ultraviolet light exposure was selected. A temperature range for the heat development of the recycled photosensitive chunks of glass such as 525 degrees Celsius, 550 degrees Celsius, 575 degrees Celsius 600 degrees Celsius was chosen. A kiln firing program was written out for each selected temperature to record the experimental results.

- Write out a kiln-firing program to record the experiment results.

### **Scoping experiments: Colour Saturation**

**5.2.2a Scoping Experiment (a). Figure 1 (a).** [Rotating turntable] under red light/safe light conditions.

**Method:**

Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery 'bat', secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a rotating turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

The kiln was programmed using a digital HARCO controller and set for the temperature of 525 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

**5.2.2b Scoping Experiment (b).Figure 2(b).** [Static turntable] under red light/safe light conditions.

**Method:**

Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery bat that was secured to the pottery wheel head under the light box.

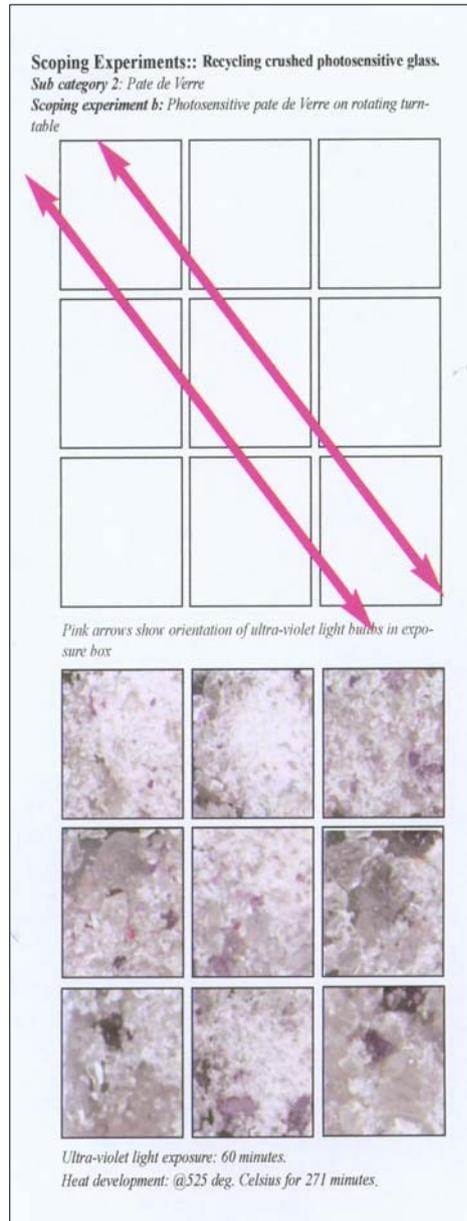
Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a static turntable. The nine ultraviolet light exposed cup

cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

The kiln was programmed using a digital HARCO controller and set for the temperature of 525 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

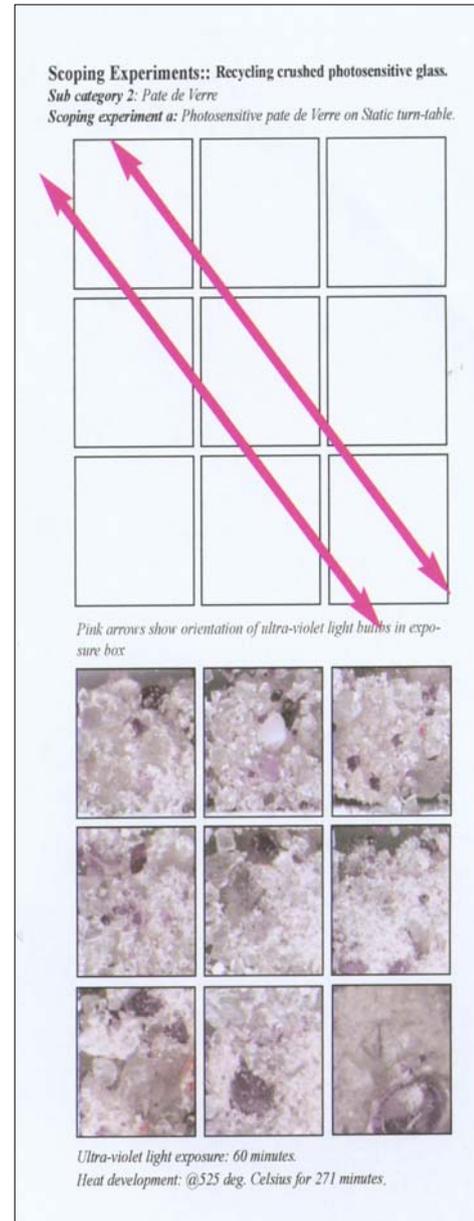
**Figure 1(a).**

Shows results from a rotating turntable.



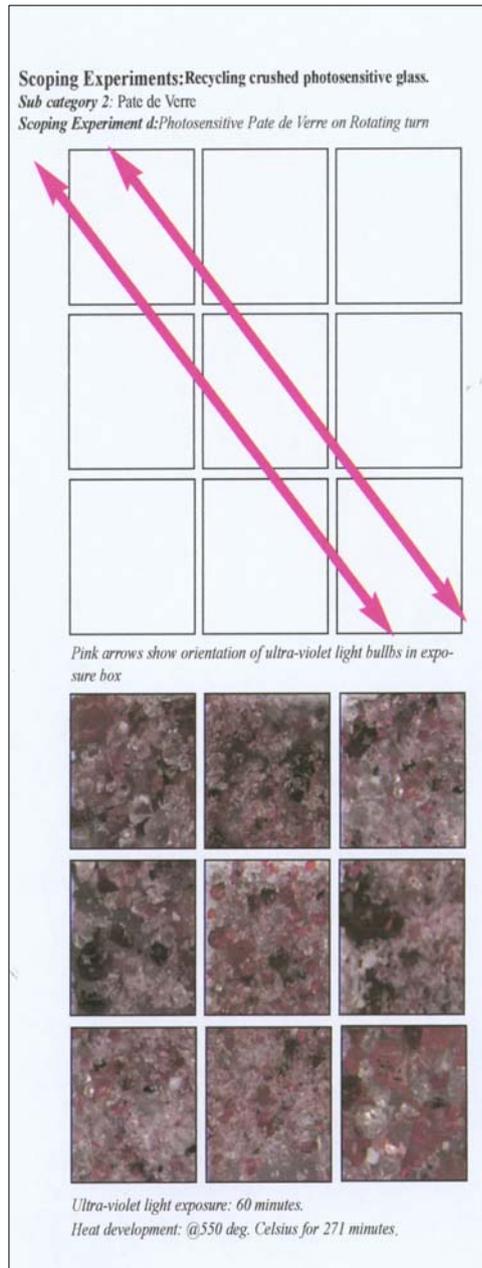
**Figure 2(b).**

Shows results from a rotating turntable.



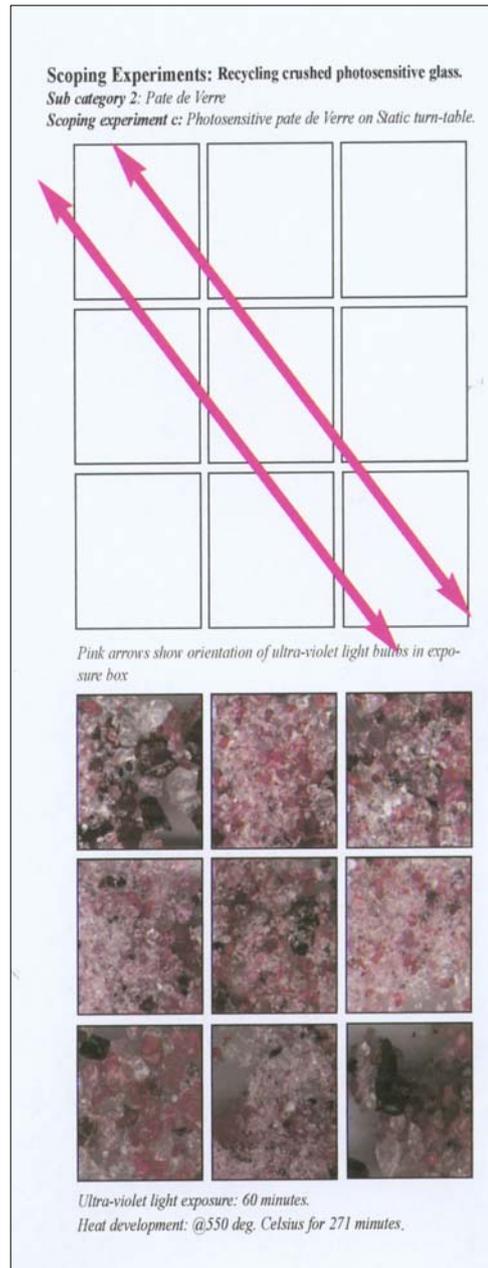
**Figure 3(c).**

Shows results from a rotating turntable.  
No variation in colour density can be seen  
in the nine boxes of this experiment.



**Figure 4(d).**

Shows results from a static turntable. Note the  
darker colours of boxes 1, 5, 9.



**5.2.2c Scoping Experiment (c). Figure 3(c).** [Rotating turntable] under red light/safe light conditions.

**Method:**

Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery 'bat', secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a rotating turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

**5.2.2d Scoping Experiment (d). Figure 4(d)** [Static turntable] under red light/safe light conditions.

**Method:**

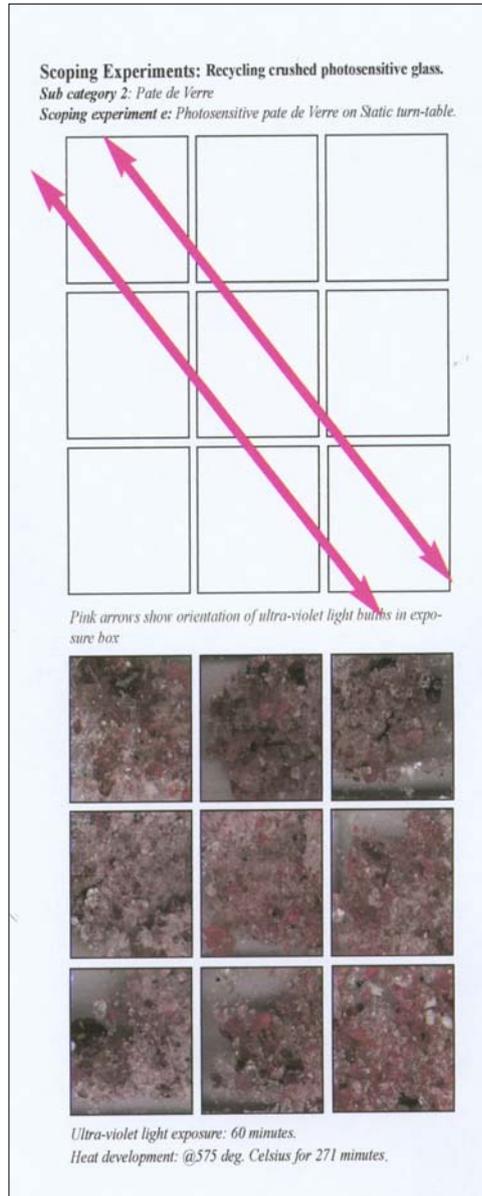
Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery 'bat', secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a static turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

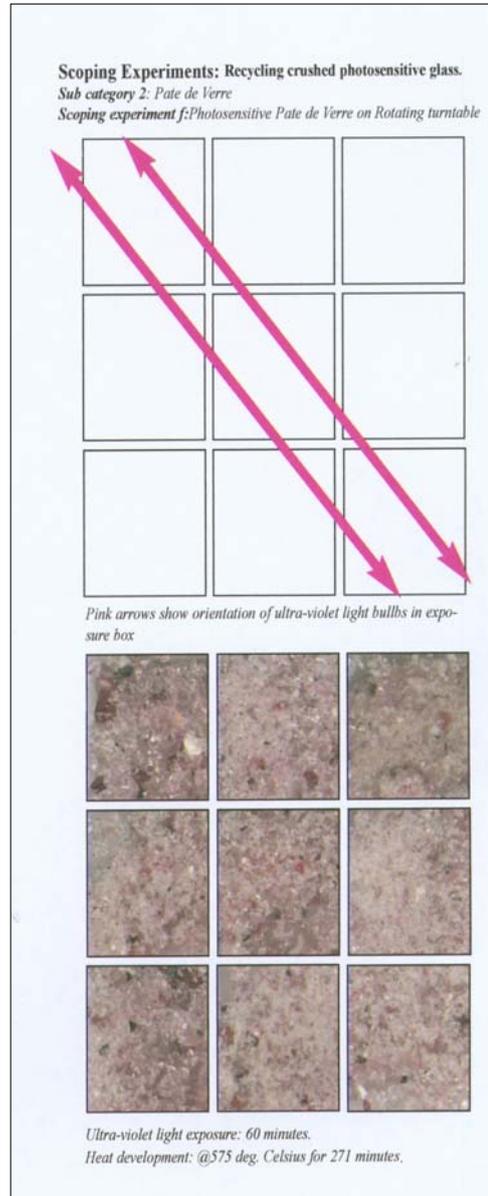
The kiln was programmed using a digital HARCO controller and set for the temperature of 550 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

The kiln was programmed using a digital HARCO controller and set for the temperature of 550 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

**Figure 5(e).**



**Figure 6(f).**



**5.2.2e Scoping Experiment (e). Figure 5(e)** [Static turntable] under red light/safe light conditions.

**Method:**

Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery 'bat', secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a static turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

The kiln was programmed using a digital HARCO controller and set for the temperature of 575 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

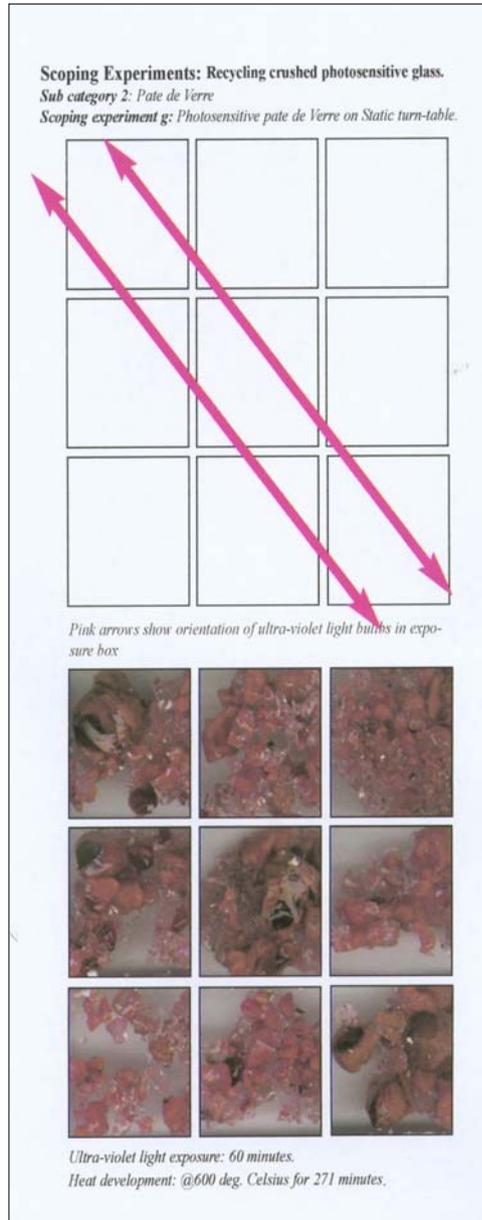
**5.2.2f Scoping Experiment (f). Figure 6(f)** [Rotating turntable] under red light/safe light conditions.

**Method:**

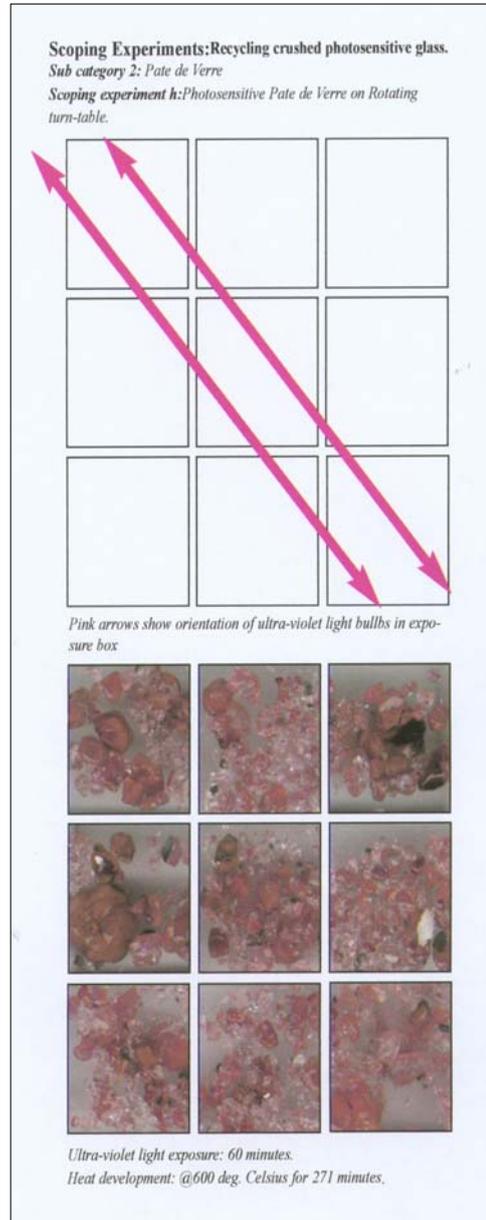
Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery 'bat', secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a rotating turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips. The kiln was programmed using a digital HARCO controller and set for the temperature of 575 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

**Figure 6(g).**



**Figure 7(h).**



**5.2.2g Scoping Experiment (g). Figure 6 (g) [Static turntable]** under red light/safe light conditions.

**Method:**

Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery bat, secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a static turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

The kiln was programmed using a digital HARCO controller and set for the temperature of 600 degrees Celsius for 271 minutes as illustrated in the kiln-firing program.

**5.2.2h Scoping Experiment (h). Figure 7(h) [Rotating turntable]** under red light/safe light conditions.

**Method:**

Crushed photosensitive glass chips off the moyle, based on the sugar granule size selected suitable for Pate de Verre, were mixed with a wall paper paste and placed into nine cup-cake containers which were pinned down on a wooden pottery bat, secured to the pottery wheel head under the light box.

Their placement distance from the ultraviolet light tubes was between 100 – 150 millimetres. The crushed chips were exposed for 60 minutes under ultraviolet light on a rotating turntable. The nine ultraviolet light exposed cup cakes were then placed into an electric kiln for heat development of the exposed photosensitive glass chips.

The kiln was programmed using a digital HARCO controller and set for the temperature of 600 degrees Celsius for 271 minutes as illustrated in the kiln-

firing program. The results were scanned using a UMAX Powerlock Scanner and printed out.

**Results:**

Comparisons between static and rotating turntable results to show relative values were made and it was observed that crushed photosensitive Pate de Verre glass chips off the moyle, ultra violet light exposed for 60 minutes then heat developed at 525, 550, 575 and 600 degrees Celsius for 271 minutes on a static turn table had darker results at numbers 1, 5 and 9 scanned printouts that those heat developed on a rotating turn table at the same temperatures and time.

**Conclusion:**

The results indicated that experiments involving shorter ultra violet light exposures such as 60 minutes rather than 100, 110 minutes on a static turn table, then heat developed at a lower temperature such as 525 degrees Celsius would give similar results to the experiment that was heat developed at 550 degrees Celsius and ultra violet light exposed for 60 minutes on a static turn table. Possible improvements in techniques used were considered in the form of Triaxial and Line blending experiments using photosensitive Pate de Verre for more controlled and informative results

**Objectives**

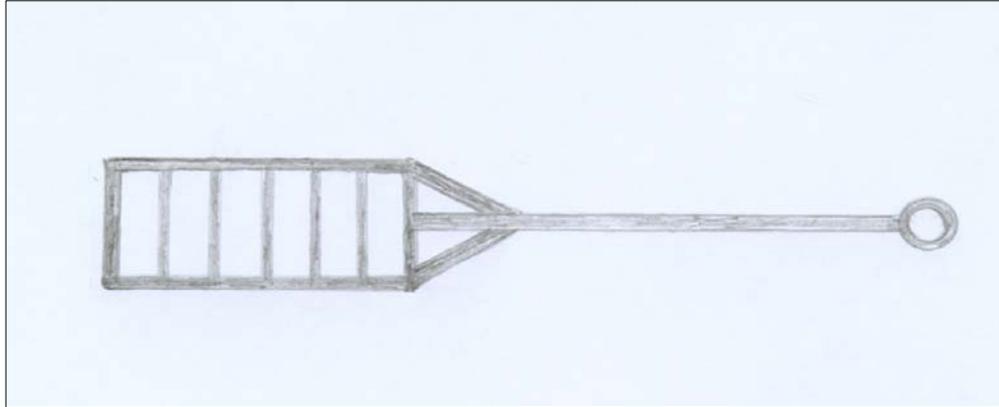
My objectives for the Pate de Verre scoping experiments are the same as those described for the scoping Chunk de Verre experiments.

**5.2.2i Scoping Experiment I: Pastorelli and glory-hole experiment**

The mould was cured according to instructions in an electric kiln, and then the variable (d) base of crushed #White Opalescent glass was packed into the bottom of the mould to a depth of 1 mm thick. The mould and its contents were first heated up to 525 degrees Celsius in the kiln before being placed onto the pastorelli.

**Figure 8(i).**

Diagram of pastorelli.



### **Process**

Two sieved photosensitive glass chips based on the sizes of sugar granules were sprinkled on top of the White Opal glass base. The pastorelli was then placed into the Glory-hole. Visual monitoring of the melting of the photosensitive glass in the mould held by the pastorelli was made. The pastorelli was withdrawn from the glory-hole when a glassy surface of the photosensitive glass could be seen. The mould containing the experiment was then placed in an annealing kiln overnight. When the mould was cool enough to wrap up, it was placed in a heavy black plastic bag to be ready for ultra violet light exposure. The experiment was exposed to ultra violet light in the light box at intervals from 15 minutes up to 90 minutes. For the heat development phase of the experiment, a HARCO digital controller an Electric kiln was used.

The positioning of the pastorelli mould in the light box was set at a distance from the ultra violet light tubes between 100 – 150 millimetres. The HARCO digital kiln programmer was set for a temperature of 600 degrees Celsius for 271 minutes as illustrated in the kiln-firing program for the first experiment. The results were scanned using a UMAX Powerlock II Scanner and printed.

### **Aim of scoping experiment I**

The primary aim of this scoping experiment was to see if assorted raw chips of photosensitive glass would melt on top of a base of crushed sieved #Opal White Gaffer glass so as to be ready for the latent ultraviolet light exposure stage. An oblong mould was made to fit onto the pastorelli from Mould Mix #6. to contain the base of crushed variable (d) #101. The mould was cured according to instructions in an electric kiln then the variable (d) base glass was packed into the bottom of the mould to a depth of 1 mm thick. The mould and its contents were first heated up to 525 degrees Celsius in the kiln before being placed onto the pastorelli. Sieved photosensitive glass chips based on the sizes of sugar granules were sprinkled on top of the Opal White base. The pastorelli was then placed into the Glory-hole. Visual monitoring of the melting of the photosensitive glass in the mould on top of the pastorelli was recorded. The pastorelli was withdrawn from the glory-hole when a glassy surface of photosensitive glass could be seen. The mould containing the scoping experiment as then placed in an annealing kiln overnight. When the mold was cool enough to wrap up, it was placed in a heavy black plastic bag to be ready for ultraviolet light exposure. The scoping experiment was exposed to ultraviolet light in the light box at intervals from 15 minutes in 5 minute increments up to 90 minutes. For the heat development phase of the scoping experiment, a HARCO digital controller and an electric kiln was used. The positioning of the pastorelli mould in the light box was set at a distance from the ultraviolet light tubes between 100-150millimetres. The HARCO digital kiln programmer was set for a temperature of 600 degrees Celsius for 271 minutes as illustrated in the kiln-firing program for the first scoping experiment. The results were scanned using a UMAX Powerlock II Scanner and printed.

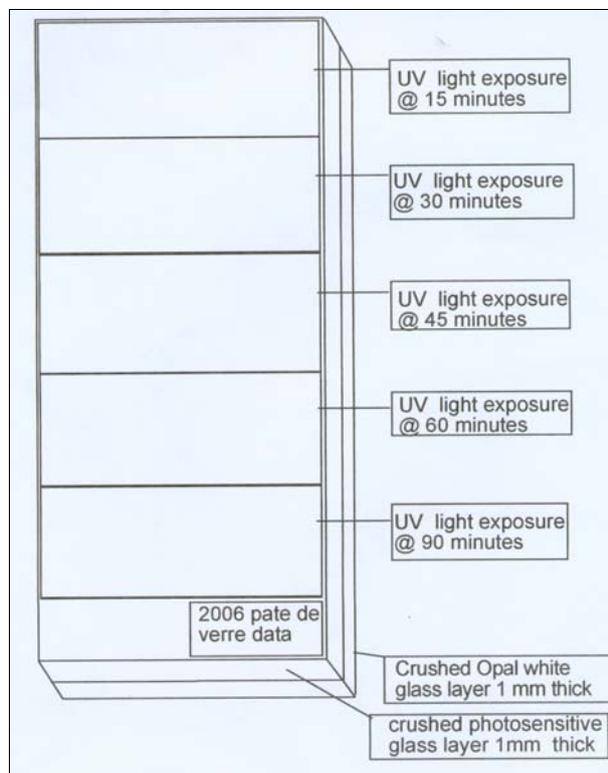
### **Results:**

This experiment was a failure

There was no varied colour development at all other than the colour red. The powdered photosensitive glass layer did not received sufficient flaming while exposed to the heat of the Glory-hole in order to strike. No further experimentation using the mould and pastorelli was made.

**Figure 9.**

Diagram of experiment on top of pastorelli after ultraviolet light exposure in defined segments and before heat development in the glory hole.



**Overview of results**

The results of the orientation of the ultraviolet light tubes situated in the top of the light-box indicated that scoping experiments involving shorter ultra violet light exposures such as 60 minutes rather than 100 and 110 minutes on a static turn table, then heat developed at a lower temperature such as 525 degrees Celsius would give similar results to the ‘scoping’ experiment that was heat developed at 550 degrees Celsius and ultra violet light exposed for 60 minutes on a static turn table.

Improvements in the techniques I used were considered and a decision to conduct further scoping experiments in the form of Triaxial and Line blends was made. Unused rods of crushed photosensitive glass were purchased and used with soda-lime furnace glass and an opaque Opal white glass for a more controlled and informative outcome. The triaxial and line-blending experiments are discussed in 5.4.0.Case Study Four, 5.4.2 sub-category 2.

## **Appendix Biii (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study Three: Bead-making/Flameworking Sub-category: 5.3.1: Bead-making**

##### **Overview of sub-category 5.3.1: Bead-making**

Bead-making/Flameworking can be defined as the process of melting and manipulating glass using a flame or torch. To-day a gas/air or gas/oxygen flame tool or burner or a bead-making torch is commonly used to make hand-made beads (Bray 2001, 153).

##### **Scoping case study project aims**

To produce a series of systematic scoping experimental results that would indicate how photosensitive glass could be incorporated into a variety of bead-making techniques through a scoping experimental approach.

##### **My research question (and specific hypothesis) that was applied to sub-category 5.3.1 of scoping Case Study Three**

How can photosensitive glass be incorporated into the technique of bead-making?

##### **Questions asked – methods to be used:**

What methods could I apply to incorporate photosensitive glass into the traditional technique of making glass beads?

What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was making glass beads?

What would occur if I used unfired, chips or crushed photosensitive glass with the molten furnace glass before I made the beads?

What would the result be if I pre-flamed a large chip of photosensitive glass in the glory hole on a punty then dipping it into the molten furnace glass before pulling the mixture to make canes for bead making?

How would I store the photosensitive glass bead experiments?

What annealing requirements are there for photosensitive glass beads?

### **Detailed questions to be asked of myself, the investigator**

- In what ways could I prepare the photosensitive glass for incorporation into the hot glass bead-making technique?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was making beads
- What would occur if I used unfired chips or crushed photosensitive glass with the bead-making cane?
- What would happened if I rolled my gather of furnace glass using a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before making the beads?
- How would I safely store the pulled photosensitive glass bead experiments prior to exposing them to ultra violet light?
- What annealing requirements are there for beads made with photosensitive glass?
- 

### **Process (standard application) and technical skills required**

#### **Foundation of a good bead**

Beads need a good foundation and this foundation is the mandrel. The mandrel is a metal rod that is covered with a bead release or bead separator at the end where the melted glass is wrapped. The most common materials used in bead release are the binder, Kaolin clay, 40% which fires hard. 30% of

Alumina hydrate makes the mix more plastic and cuts down on the shrinkage as well as enabling the mixture to withstand high temperatures. 25% of Whiting or Talc are both sources of calcium carbonate which make the bead release more porous. Adding 5% – 10% powdered Graphite makes the bead slide off easier and the hole cleans out easier. This bead release formula is used by Kerkvliet (1995). Before mixing up the bead release it is important to wear a respirator as the ingredients are measured by dry weight.

Many types of materials such as copper, brass, ordinary steel and stainless steel can be used for mandrels. I prefer using a stainless steel mandrel because it is capable of withstanding high temperatures without bending and the surface remains smooth even after many beads have been made on the mandrel.

Using a bead-making torch and powdered photosensitive glass and chips of small, medium and large sizes of photosensitive glass together with Spectrum #96 bead-making canes of glass some scoping beads were attempted. In addition to making beads using the oxygen and gas bead-making torch I fired-up my miniature home-made “*small fire*” furnace, similar to Dudley Giberson’s description of his ‘*hot volcano*’ cone shaped furnace to make some additional ‘scoping’ beads. The Photosensitive glass rod was measured, cut up into medallion sized pieces, weighed then crushed into large chips. These chips were then placed into a crucible in the miniature furnace to become molten glass. The molten glass was gathered on a mandrel and shaped into a bead using the heat from the top of the furnace. The technical skills needed to make a bead are deceptively demanding as it requires many hours of practice.

**Result:**

The scoping experiment was unsuccessful.

**Conclusion:**

My assumption is that the high temperature of the photosensitive glass in the crucible of the miniature furnace was responsible for the appearance of the dull dirty-red colour of the competed beads. It is postulated that the chemical balance of the ingredients of the photosensitive glass were overheated and

could not react to the exposure stage under ultraviolet light nor the timed heat development stage.

Lamp-working/Bead-making techniques are described in simple terms, as well as giving ample scientific formulae by Scott, Dunham Bandhu (1995). In addition Scott Dunham covers many other details on set up and safety in the studio when bead-making.

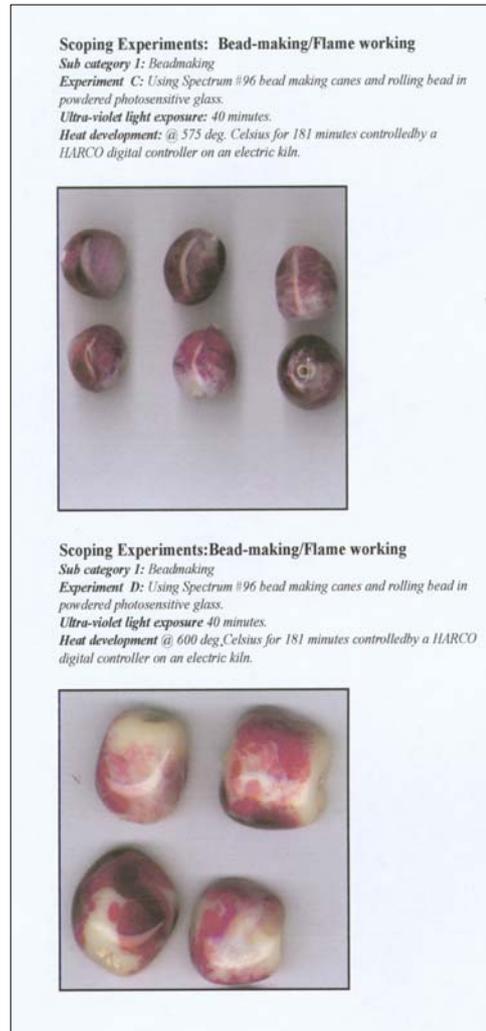
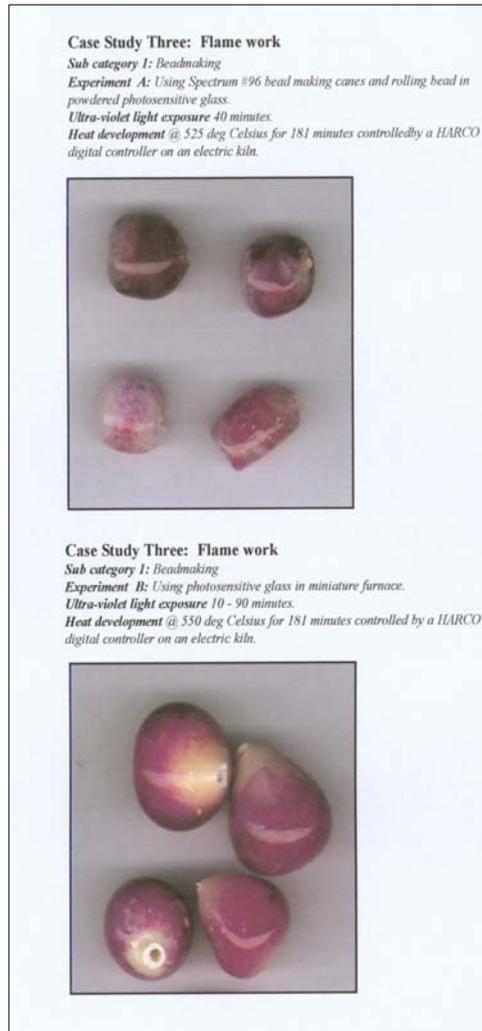
### **Methods of making glass beads**

There are a number of ways of making beads using glass. The three principle methods are wound, drawn and fused. Beads can be made by drawing molten glass to form a long thin tube, which can then be cut into many beads or by placing glass in moulds and heating the moulds in a kiln until the glass fuses together. Beads can be made by winding molten glass onto a mandrel to form a bead. There are two variations on the above techniques; with the mould-pressed bead making technique, the molten glass from the furnace is forced into a mould to give the beads a distinct shape. Bead manufacturers use this method to produce a large number of shaped beads. Mosaic beads are made by fusing slices of drawn canes into a wound or drawn-glass body. The winding of molten cane glass onto a mandrel technique was used for the following photosensitive glass experiments. Wound beads are produced by winding a hot and molten rod or cane of glass or strand drawn from molten glass (stringer) around a metal wire mandrel. The bead-maker sits in front of the heat source, (a gas and oxygen bead making bench burner) heating the cane of glass and winding the cane onto the mandrel. The gas and oxygen fuels mixed together produce a very hot flame in which the glass cane is melted and wrapped around the mandrel coated with bead release to prevent the bead from sticking to the metal. Beads made using this technique are also referred to as lamp-wound beads. While the bead is still soft, the bead-maker can decorate the bead with many decorating techniques such as inlays or appliqué. The most popular glass for lampworking/bead-making is soda-lime glass and it is

available pre-coloured. Most lamp-workers/bead-makers use rods of glass 7-8 mm in diameter. Sheet glass can be cut with tools into strips and powdered glass is also available in particles of various sizes. Powdered glass or frit is typically used for surface decoration on the bead. Sheet glass can be cut with tools into strips and powdered glass is also available in particles of various sizes. Powdered glass or frit is typically used for surface decoration on the bead.

**Figure 1. (A & B).**

**Figure 2. (C & D).**



**Figure 1. (A).**

**5.3.1a Scoping experiment A (canes).**

**Process (Standard applications) and technical skills required for Bead-making.**

Spectrum #96 canes of white opaque glass were used in this experiment because Spectrum #96 is compatible with the soda lime photosensitive glass. Part of a rod of photosensitive glass was broken off and crushed into a very fine powder. This activity took place in a darkroom under red photographic light so as to minimize exposing the photosensitive glass to any ultra violet light in the studio. The fine photosensitive powder was placed in a flat stainless steel container and covered with a piece of thick black plastic while the bead was being made by my collaborating colleague. When the bead being made was sufficiently hot and molten enough, it was rolled in the photosensitive powder then returned to the fire of the torch to melt it in to the body of the bead glass. This rolling of the bead in the molten photosensitive powder process was repeated twice before finishing off the bead and placing it in the annealing kiln (lehr). The beads were kept on their mandrels for the ultraviolet light exposure stage of the experiment. The mandrels were placed into a container of damp sand to hold them in position while they were been exposed to ultra violet light in the light box. This container of sand was placed onto the potter's wheel turntable, so that all the beads could be suitably exposed as the wheel-head rotated under the ultra violet light. The first set of beads were removed after forty minutes, then the next set removed ten minutes later until ninety minutes exposure time had been reached. After the required annealing time had been completed, the eighteen beads were removed from the (lehr) then placed in a dark light proof container to await the ultraviolet light exposure process.

Eighteen beads were needed for scoping experiments with six ultraviolet light exposures from 40 minutes to 90 minutes. Once the ultra violet light exposure stage had been completed, the beads were marked with their exposure times under red photographic light. The marked beads were then replaced into the dark light proof container until they were heat developed in an electric kiln using a HARCO digital controller. The photosensitive beads were heat

developed at the three temperatures of 525, 550, 575, 600 degrees for 181 minutes (three hours).

**Results:**

The results were disappointing in that the colour of the photosensitive glass powder coating on the Spectrum#90 Opalescent White beads appeared to have been over exposed. Over exposure is assumed because of the dull pinkish-red colour of all the beads.

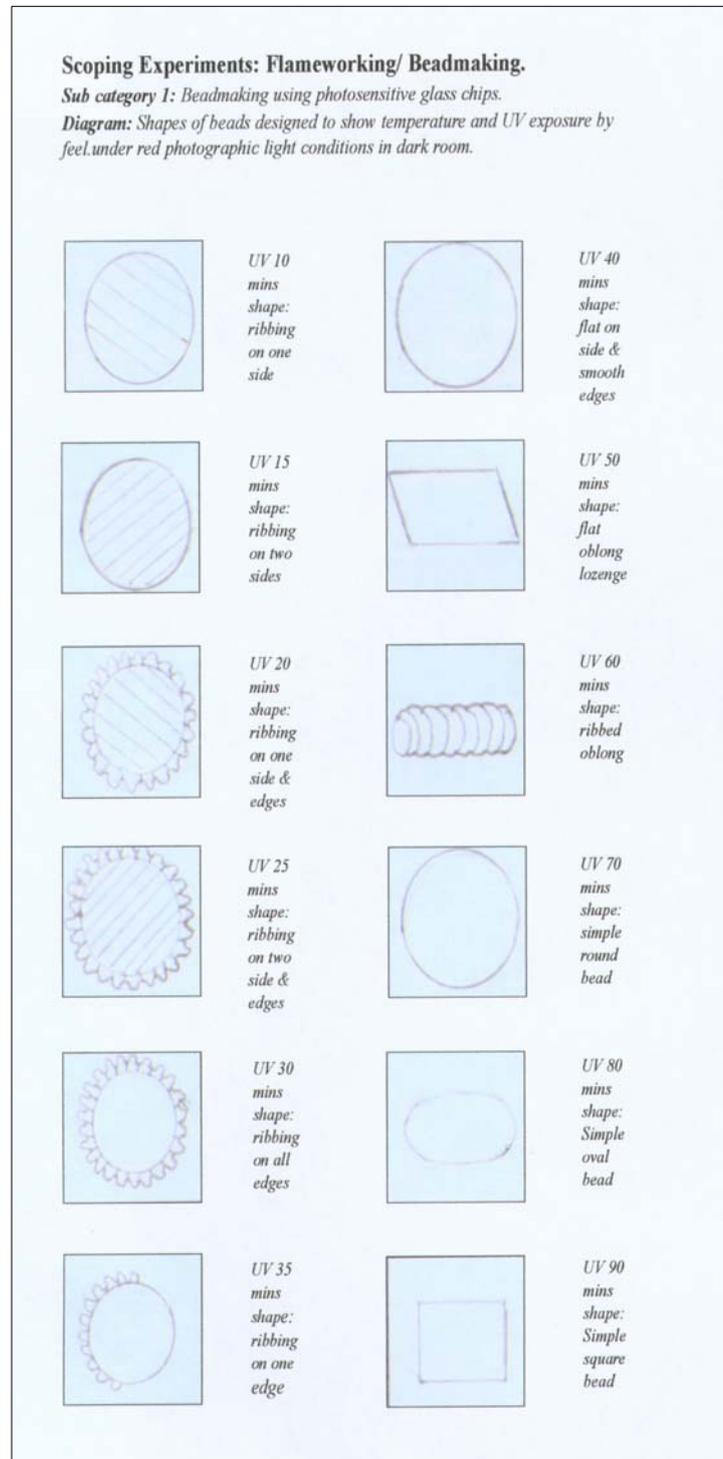
**Conclusion:**

It is suspected that this over exposure could have occurred either during the photosensitive glass powder coating stage caused by the latent ultraviolet light in the room and/or by the heat of the bead-making torch.

It was at this point in my research that I considered it important for recognition purposes that each bead needed to have its own shape to correspond with its ultraviolet light exposure time. This realisation was reached because working in the darkness or under safe red photographic light it became difficult to remember the ultraviolet light exposure times of each bead. Recognising the ultraviolet light exposure time by the feel of the shape of the bead, ensured that fewer errors would be made. Individually shaped beads would also minimize recognition confusion at the heat development stage. The initial time for three hours (181 minutes) for heat development at the selected four temperatures was based on extending the length of time exposure that had been given to the stringer and murrine experiments.

**Figure 3.**

Different shapes for photosensitive glass beads.



**Figure 1. (B).**

**5.3.1b Scoping experiment B** (in miniature furnace).

**Results:**

The results were disappointing as were the results of the photosensitive powder coated glass bead. The overall dull dark-pink colour appeared to be more even than the powder coated beads due to the '*dipping*' of the bead into the molten glass of the crucible at the gather stage. There was no gradation of colour according to the length of time the beads were exposed at the ultraviolet light stage. All ten beads were the same colour.

**Figure 2. (C).**

**5.3.1c Scoping experiment C** (canes).

When the bead being made was sufficiently hot and molten enough it was rolled in the photosensitive powder then returned to the torch to melt the powder into the Opalescent White bead on the mandrel. This rolling of the molten bead in the photosensitive powder process was repeated twice before finishing off the bead and placing it in the annealing kiln. The beads were kept on their mandrels for the ultra violet light exposure stage of this experiment. The mandrels were all placed into a container of damp sand. The container of sand was then placed onto the potter's wheel turntable, so that all the beads could be equally exposed as the wheel-head rotated under the light box. The beads were removed from the light box after forty minutes then heat developed in an electric kiln using a HARCO digital controller at a temperature of 575 degrees Celsius for 181 minutes (three hours).

**Results:**

As in experiment A, the results were similarly disappointing. The higher temperature resulted in the beads becoming light pink-reds, and dark, dusty-reds.

**Conclusion:**

I suspect that when the powdered photosensitive glass became exposed to the latent ultraviolet light present in the workshop/studio during the melting stage

onto the Spectrum#96 Opalescent White bead or when powdering the photosensitive glass, the material properties of the glass were altered.

**Figure 2. (D).**

**5.3.1d Scoping experiment D (canes).**

Experiment D was subjected to the same processes as experiments A and C. The only difference was the heat development temperature of 600 degrees Celsius for the same time in the electric kiln.

**Results:**

The colour red was deeper and clearer as was expected due to the higher heat development temperature.

**Conclusions:**

I concluded that photosensitive glass powder coated beads should be made in a darkened workshop area to minimize the ultraviolet light from the room and bead-making torch that may have affected the bead during the making process. The length of time and high temperature during heat development is also suspected of having had an effect on the final colour of the photosensitive powder coated glass bead.

I suggest that to overcome the problems associated with the making of photosensitive powder coated glass beads, heat development of these beads at the lower temperature ranges of 495 and 505 degrees Celsius would give improved results. At these lower temperature ranges more varied colour results should occur.

**Figure 4. (E).**

**5.3.1e Scoping experiment E (canes).**

Using my miniature home made “*small fire*” furnace, similar to Dudley Gilbertson’s description of the “*hot volcano*” cone shaped furnace, I crushed up a photosensitive glass rod into medium size pieces, weighed the pieces and placed them into the furnace crucible for melting down. While the photosensitive glass pieces were melting in the crucible inside the furnace ten

beads of Spectrum #96 were made on mandrels using the heat rising from the hole at top of the furnace. The Spectrum #96 beads were plunged into the molten photosensitive glass in the crucible. The crucible was accessed through a port on the side of the dome of the furnace. The dome of the furnace was altered to make a side port for access because I found that accessing the molten glass from the dome caused my glove to smoulder from the heat escaping. Once the photosensitive molten glass was gathered onto the bead, it was marvered and shaped before placing it into an annealing kiln on its mandrel.

The ten beads were exposed to ultra violet light in the light box on their mandrels from 10 minutes to 90 minutes. Then they were heat developed @ 550 degrees Celsius for 181 minutes in an electric kiln using a HARCO digital controller.

**Results:**

The results were varied and some beads showed signs of a mauve colour within the clear red to dark-red colour. I suspect that the light clear red colour was due to a few medium sized photosensitive glass chips that melted onto the bead.

**Conclusion:**

I am of the opinion that the scoping experiment was successful because it showed that colour development other than a clear red was possible. Colour development of blue-mauves, mauves to purples together with a variety of red colours was seen. This colour development I suspect is due to the ultraviolet light exposure time, the lower temperature and the length of time for the heat development stage and may be the factors responsible for the appearance of a mauve colour within the clear red colour.

**Figure 4. (F).**

**5.3.1f Scoping experiment F (canes).**

When the bead being made from a cane of Spectrum #96 was sufficiently hot and molten enough it was rolled into the medium sized photosensitive glass

chips then returned to the bead-making torch to melt them in before making the bead into a square shape. This rolling of the molten bead in the photosensitive glass chips process was repeated twice before finishing off the bead and placing it on its mandrel in the annealing kiln. The beads were kept on their mandrels for the ultra violet light exposure stage of the scoping experiment as described in Scoping experiment A. The beads were removed from the light box after 40 minutes, then heat developed in a HARCO controlled electric kiln at a temperature of 550 degrees Celsius for 181 minutes (3 hours).

**Results:**

Results were varied and some beads showed patches of a mauve and purple colours within the clear reds and dark-red colours of the 'square' shaped bead. Development signs of small blue-mauve areas could be seen in some beads.

**Conclusion:**

The experiment was successful in showing that colour development of blue-mauves, mauve to purples together with a variety of red colours was possible. This colour development I believe is due to following factors; the thickness of the chips of photosensitive glass together with the shorter time in getting them to become incorporated with the Spectrum#96 bead as well as the ultraviolet light exposure time, medium hot temperature and length of time for heat development.

**Figure F. (G).**

**5.3.1g Scoping experiment G (canes).**

The beads in this scoping experiment were made using the process as described in Scoping experiment A. The beads were removed from the light box after being exposed to ultraviolet light for 40 minutes. They were then heat developed in a HARCO controlled electric kiln at a temperature of 575 degrees Celsius for 181 minutes (3 hours).

**Results:**

The colours of these beads were similar to those on the colours of the miniature furnace made beads. They showed irregular patches of thin dull-red colour together with a very dark-red colour.

**Conclusion:**

This Scoping experiment was unsuccessful. I conclude that the high temperature of 575 degrees Celsius at the heat development state was the cause of the dull-red and dark red colours.

**Figure 5. (H).****5.3.1h Scoping experiment H (canes).**

The beads, made as described in scoping experiment A were removed from the light box after 40 minutes ultraviolet light exposure after which they were heat developed in a HARCO controlled electric at a temperature of 600 degrees Celsius for 181 minutes (3 hours).

**Results:**

The colours on these beads ranged from pink (control bead with no ultraviolet light exposure) to medium red to very dark-red colours.

**Figure 6. (I).****5.3.1i Scoping experiment I (in miniature furnace).**

A set of four beads was made using the heat from the top of the miniature furnace as described in scoping experiment B so I worked as quickly as it was possible to test the time frame factor. After annealing, the beads were masked to exclude areas from ultraviolet light exposure. They were then heat developed @ 575 degrees Celsius for 181 minutes.

**Results:**

The three ultraviolet light exposed photosensitive glass beads A, B & C appear to have a 'burnt' dull-red to brownish-red colour. The control bead remained pinkish-cream because it had not been exposed to any ultraviolet light. The band of light dull-pink in the middle of each bead is where the ultraviolet light

was excluded after ten minutes of exposure. There is no sign of any difference the base of the bead @ 40 minutes ultraviolet light exposure and the top of the bead @ 60 minutes exposure.

**Conclusion:**

The colours of the three beads indicated that the photosensitive glass was '*overcooked*' in the furnace. I suggest that the length of time taken for heat development may have been too long and the temperature too high. I presume that melting photosensitive glass rod chips in a crucible of miniature furnace for gather purposes did not produce results similar to melting chips of photosensitive glass chips directly into the body of the bead using a bead-making torch. It is possible that the photosensitive glass which was melted down in the miniature furnace crucible may have had its chemical metallic properties altered.

**Figure 6. (J).**

**5.3.1j. Scoping experiment J (in miniature furnace).**

A set of beads was made using the heat from the top of the miniature furnace as described in scoping experiment B After annealing, the beads were exposed to ultraviolet light for 100,105 and 110 minutes in the ultraviolet light box then heat developed @550 degrees Celsius for 181 minutes in a HARCO controlled electric kiln.

**Results:**

Bead 100 minutes exposure under ultraviolet light and Bead 105 minutes exposure have developed a clear red colour and bead 110 minutes has a dark-red colour.

**Conclusion:**

It is assumed that 181 minutes of heat development time is responsible for the clear reads of bead 100 minutes and bead 105 minutes. It is assumed that the dark-red colour of bead 110 minutes is due to either the ultraviolet light exposure being too long or that the molten photosensitive glass in the crucible had reached the '*cooked*' time factor.

**Figure 7. (K).**

**5.3.1k Scoping experiment K** (in miniature furnace).

A set of twelve beads was made using the heat from the top of the miniature furnace as described in scoping experiment B. The beads were annealed and then exposed to ultraviolet light from 10 to 90 minutes at 5 minute increments. They were then heat developed @ 550 degrees Celsius for 181 minutes in a HARCO controlled electric kiln.

**Results:**

The results were very disappointing in that all the beads appear to show a '*cooked*' or '*burnt*' colour red.

**Conclusion:**

I suspect that the problem lies with the molten photosensitive glass in the crucible. The properties of molten photosensitive glass need to be examined scientifically by a glass analyst as I suspect that the chemical nature of the glass has been altered by the melting down in the crucible

**Figure 4. (E & F).**

**Scoping Experiments: Bead-making/Flame working**  
**Sub category 1: Beadmaking**  
*Experiment E: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
**Ultra-violet light exposure:** 40 minutes.  
**Heat development:** @ 525 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.

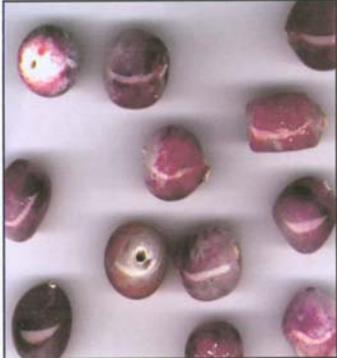


**Scoping Experiments: Bead-making/ Flame working**  
**Sub category 1: Beadmaking**  
*Experiment F: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
**Ultra-violet light exposure:** 40 minutes.  
**Heat development:** @ 550 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.



**Figure 5. (G & H).**

**Scoping Experiments: Bead-making/ Flame working**  
**Sub category 1: Beadmaking**  
*Experiment G: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
**Ultra-violet light exposure:** 40 minutes.  
**Heat development:** @ 575 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.



**Scoping Experiments: Bead-making/Flame working**  
**Sub category 1: Beadmaking**  
*Experiment H: Using Spectrum #96 bead making canes and rolling bead in medium size chips of photosensitive glass.*  
**Ultra-violet light exposure:** 40 minutes.  
**Heat development:** @ 600 deg. Celsius for 181 minutes controlled by a HARCO digital controller on an electric kiln.



Figure 6. (I & J).

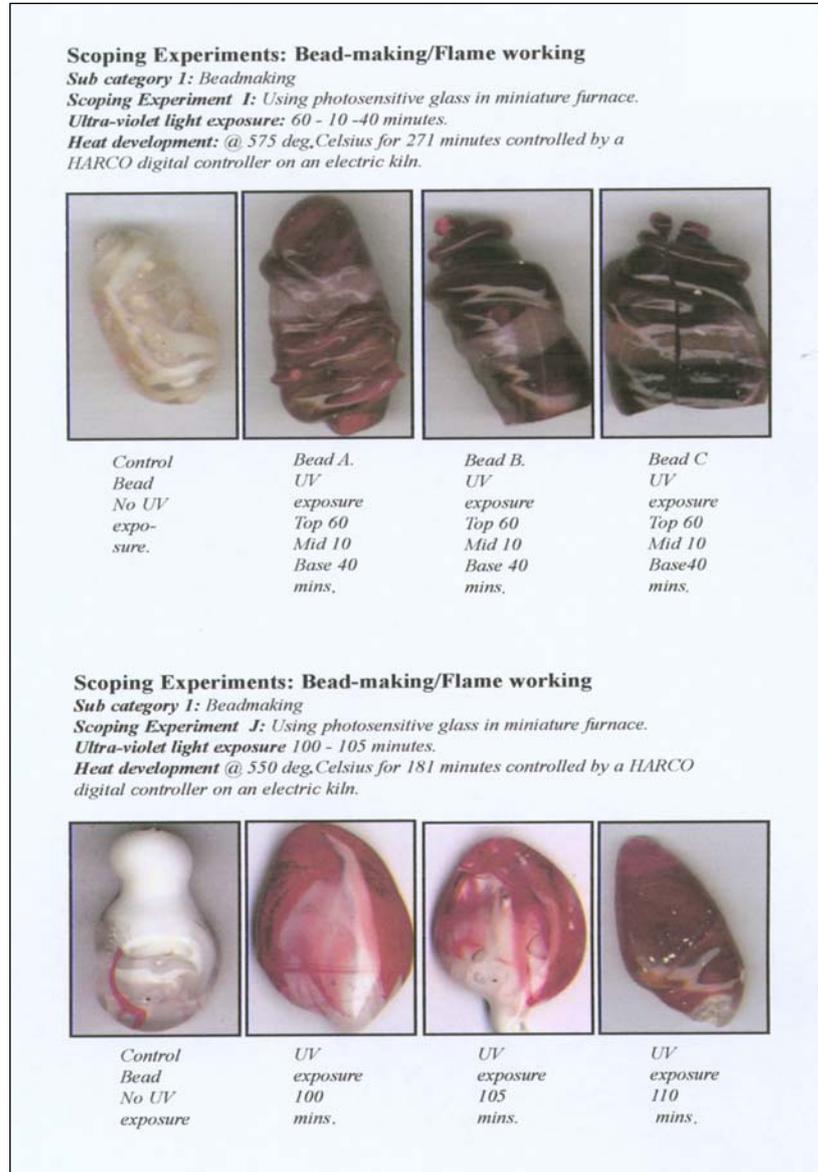
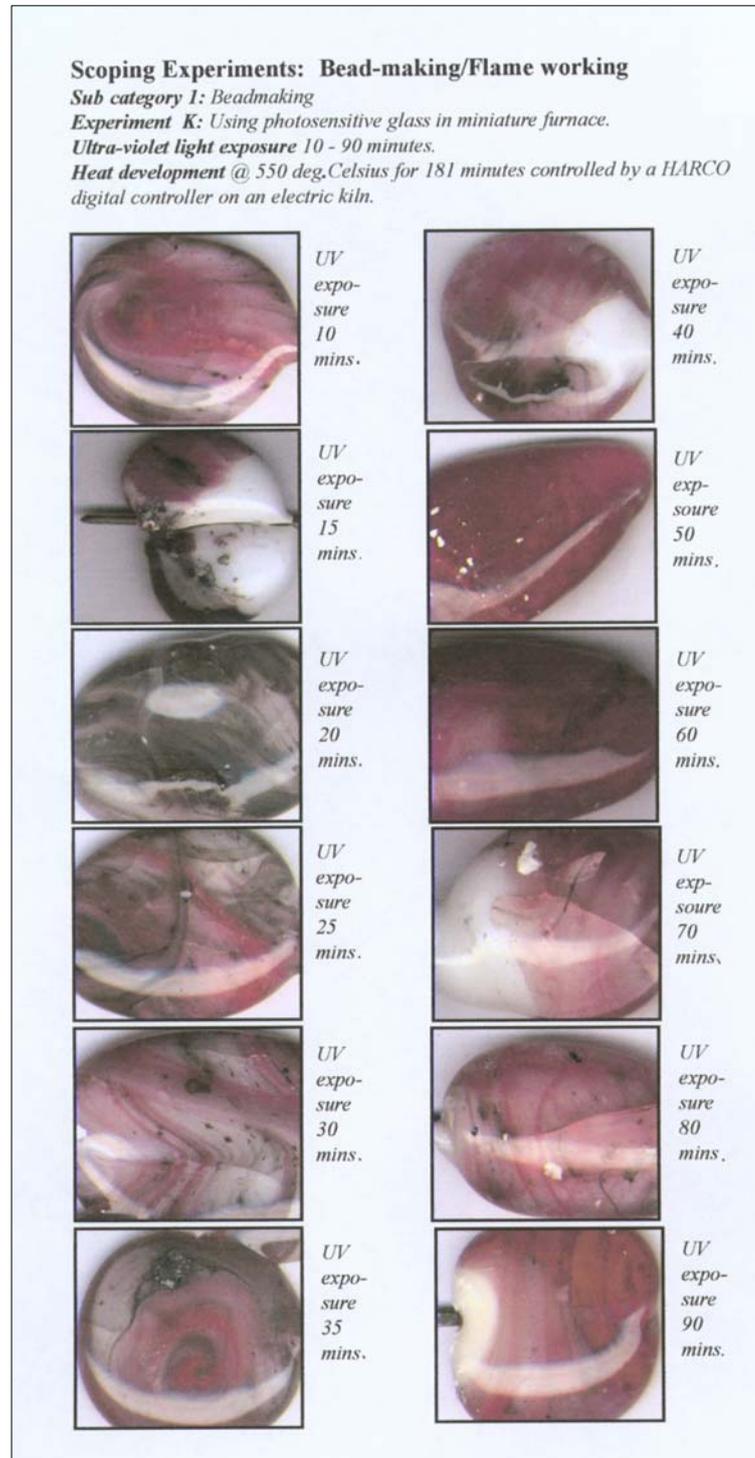


Figure. 7. (K).



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Dunham Bandhu, Scott. 1995. *Contemporary Lampworking – Guide. Shaping glass in a flame.* Science and Technology. Prescott AZ: Salusa Glassworks.

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## **Appendix Biii (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Three: Bead-making/Flameworking**

##### **Sub-category: Button making**

##### **Overview of sub-category: Button making**

Button making is a branch of bead-making. The button is used as an ornament as well as in a functional of fastening clothing.

##### **Scoping Case Study project aims**

To produce a series of systematic scoping experimental results with the objective of indicating how photosensitive glass could be incorporated into glass button making.

##### **My research question (and specific hypothesis) that was applied to sub-category 5.3.2. of scoping Case Study Three**

What and how many methods can I apply to incorporate photosensitive glass into the traditional technique of button making?

##### **Detailed questions to be asked by myself, the investigator**

In what ways could I prepare recycled photosensitive glass for making buttons?

- What would happen if I used re-cycled crushed photosensitive chips or powder when I was making buttons?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before cooled it then crushed it before adding it to the base button making cane?
- What would happened if I rolled my gather of furnace glass using a punty into crushed photosensitive glass powder or crushed chips then heated the mixture in the glory-hole before cooling and re-crushing the mixture before using it when making photosensitive glass buttons?
- How would I grade the crushed sieved photosensitive glass pieces> (Sugar?) to use in button making?
- How would I safely store the crushed chunks of recycled and new photosensitive glass experiments before to exposing them to ultra violet light?
- What annealing requirements are there for crushed recycled and new photosensitive glass buttons?

### **Process (standard application) and technical skills required**

The technical skills required to make buttons were very similar to the technical skills used in bead-making (described in sub-category 5.3.1 of this scoping case study).

### **Issues**

#### Physical Issues

One of the physical issues was the amount of light present in the studio while making the buttons using bead-making equipment. Annealing the buttons then keeping the buttons out any daylight before ultraviolet light exposure. After ultraviolet light exposure it was an issue to have a flat bed kiln available for time and heat development. It was important to remember to check that the ultraviolet light bulbs were in perfect working condition and to have a replacement bulb if necessary.

## **Identification of a range of experimental issues:**

### **Button making**

Access to bead-making equipment to carry out the scoping experiments was an issue and another issue was having access to an annealing kiln, a flat-bed kiln and knowing that there was adequate safety equipment close at hand in case of an accidental health or fire emergency. In addition the following questions were some of my experimental issues:

- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was making buttons?
- What would occur if I used unfired, chips or crushed photosensitive glass in the body of a button then fired them to a selected temperature after exposing them to ultraviolet light?
- What would happen if I used photosensitive as a casing glass over an opaque glass before dipping them into the furnace glass then crushing them when they had cooled before incorporating this mixture into a button?
- How long could I store the photosensitive glass buttons before exposing them to ultra violet light?
- What annealing requirements are there for photosensitive glass buttons to avoid distortion?

Two scoping experiments were carried out

### **5.3.2a.Experiment 1. Figure 1.**

#### **Process**

Six buttons were made by my collaborating colleague Mrs Trudy Hardman. Spectrum #96 opal white glass cane and large photosensitive glass chips were used. A special style of double mandrel was made for these buttons so as to give them two holes in the centre. Once the buttons were annealed they were exposed to ultra violet light in the light box from 10 to 60 minutes then heat

developed in an electric kiln using a HARCO digital controller for 181 minutes at a temperature of 550 degrees Celsius.

**Results:**

The colour results were narrow in range. The button exposed to ultraviolet light for only 10 minutes was the exception. It was pale white-pink unlike the buttons exposed from 20 minutes to 60 minutes. These five buttons ranged from medium mauves at 20 minutes, medium purple at 30 minutes, pale mauves and purple at 40 minutes to red-purples at 50 and 60 minutes. A special style of double mandrel was made for these buttons so as to give them two holes in the centre.

**Conclusion:**

I believe that there is potential in designing a range of firing schedules to suit the making of buttons. This firing range needs to deal with the heat development temperatures so that optimum colours can be achieved as well as keeping the especially made holes for sewing the button onto the garment.

**5.3.2b Experiment 2.**

Using Spectrum #96 Opalescent White glass canes, ten buttons were made using the bead-making torch.

**Process**

Each button was rolled into large photosensitive glass chips then re-heated in the flame of the torch to melt the photosensitive glass into the bead. The ten buttons were annealed before being exposed to ultra violet light from ten minutes to 30 minutes. Five of the buttons were then heat developed in an electric kiln using a HARCO digital controller for 90 minutes at a temperature of 495 degrees Celsius. The other five buttons were heat developed for 120 minutes at a temperature of 505 degree Celsius.

**Results:**

The results were disappointing and showed no difference in colour. Ultraviolet light exposure had been from ten minutes to thirty minutes for two different temperatures and for two different lengths of time during heat development.

All ten buttons were of a similar red. A lighter red could be seen where the photosensitive glass chip was thin and a dark-red where the chip had been thicker. The special double holes in all the buttons had by this time disappeared.

**Conclusion:**

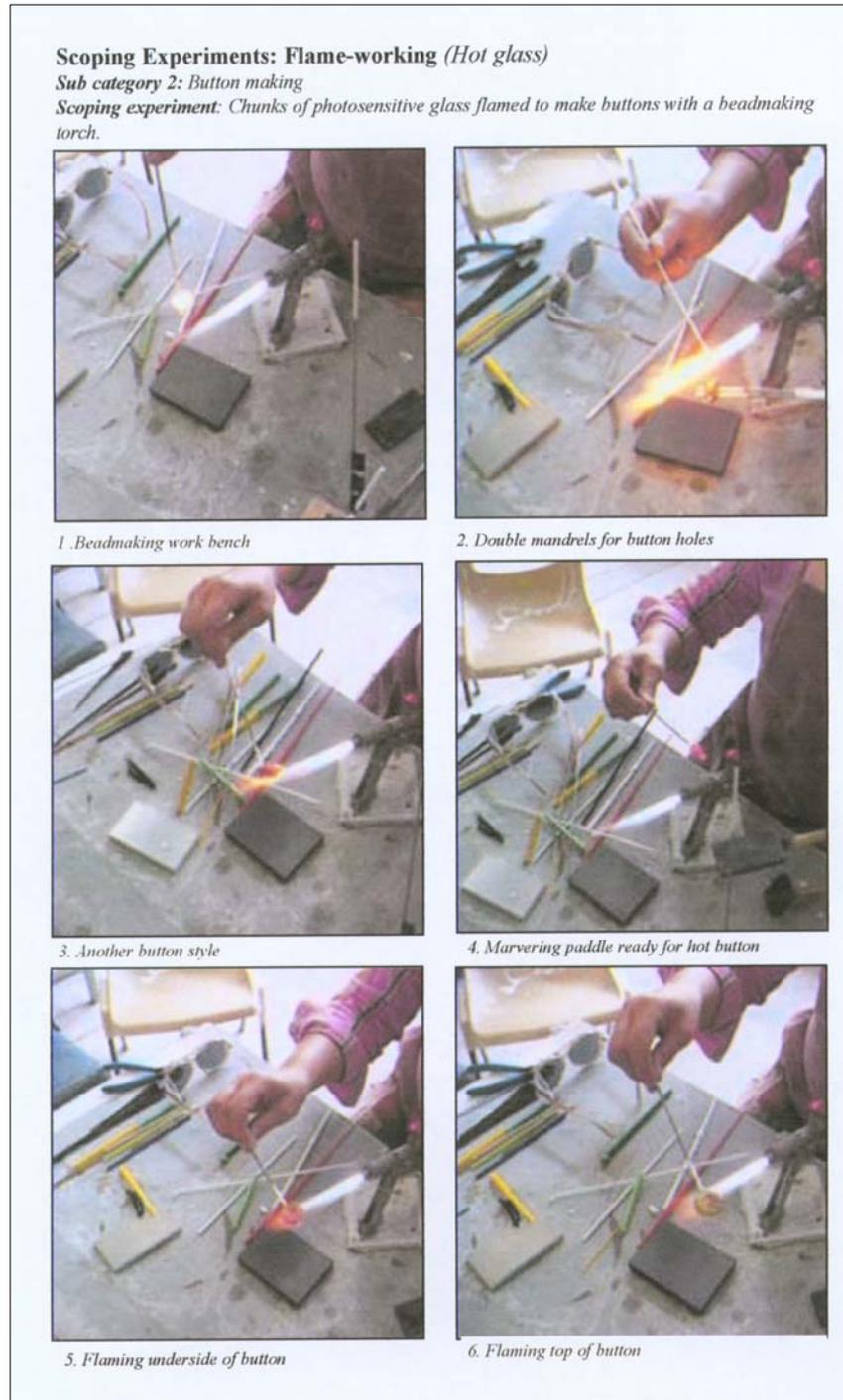
Scoping experiment 2 of 5.3.2a was considered unsuccessful.

**Figure 1.**



**Figure 2.**

Making photosensitive glass buttons using a bead-making torch.







## **Appendix Biii (c)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Three: Bead-making/Flameworking**

**Sub-category 5.3.3. Rod and Core forming** (a bead-making process).

#### **Overview of sub-category: Rod and core forming**

Core forming is a technique related to one of the methods of bead-making and is the process of coating a form on the end of a rod with molten glass to make a vessel. A rim, handles and a foot may be applied to the vessel. The rod used in this procedure is called a mandrel.

#### **Scoping case study project aims**

My aims were to experiment with as many known ways possible in making the actual cores and then applying the photosensitive glass to the core before exposing the core formed objects to ultraviolet light before heat developing them in an electric kiln using a digital controller. My objectives were to reproduce formed glassware in the ancient manner using photosensitive glass for decorative purposes.

#### **My research questions (and specific hypothesis) that was applied to sub-category 5.3.3**

What methods can I use to incorporate photosensitive glass into the traditional technique of core forming?

Is there a modern core forming material being used today?

**Detailed questions to be asked of myself, the investigator**

- In what ways could I prepare the recycled photosensitive glass for making core formed vessels?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was making core formed vessels?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before cooled it then crushed it before adding it to the base core formed vessel?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before cooling it and then crushing it?
- How would I grade the crushed sieved photosensitive glass pieces to attach to the core?
- How would I safely store the cores of photosensitive glass experiments before to exposing them to ultra violet light?
- What annealing requirements are there for core formed vessels?

**Process (standard application) and technical skills required.**

**Technical issues**

Technical issues regarding the making of a core vessel can be divided into two major sections.

- Making a core and
- Covering the core with glass to make a hollow vessel.

**Making the core**

The traditional core consisted of a combination of clay and sand (but not sand alone) with an organic binder such as dung. This material was then shaped into a vessel by building up a thick core of material around a metal rod (mandrel).

### **Making the vessel**

Making the vessel involved covering the core with hot glass either by dipping it into a crucible or more probably, by repeatedly trailing glass over the core. The outside of the vessel was then rolled, or marvered, on a flat stone surface, to make it smooth. Decoration in the form of trails or blobs was applied and often combed into feather or festoon patterns, before it, too, was marvered into the surface. Once the bottle was annealed, the metal rod could be removed and the core scraped out. Handles, lugs and bases were either applied separately or drawn out from the body while the glass was hot (Bray, 2001,85).

### **Materials used**

A combination of clay and sand with an organic binder such as any dung made up the core. This core was covered over with hot glass, either by dipping it into a crucible or, by trailing glass over it until it was completely covered. Once the core had been covered, the outside while still hot was then rolled or marvered on a flat stone surface to make it smooth. Trails and blobs that were applied. This decoration was often combed into feather or festoon patterns before being marvered into the vessel surface.

The metal rod could be removed once the bottle had been annealed and the core scraped out, leaving a rough, pitted, and usually reddish inside. Handles, lugs and bases were either applied separately or drawn out from the body while the glass was hot.

### **Alternative methods used in core making techniques**

One suggested method is that hot glass was trailed around a core form that was made up of sand or a mixture of sand, clay and camel dung. Another suggested method, is that a core was dipped into molten glass, rotated during

the gathering of the glass then marvering this gather into the required shape before adding decorative trails to it<sup>1</sup>.

The third method suggested is that a tapered metal rod was coated with a mixture of powdered glass and binder over a layer of sand. Then it was heated until the binder burned off and a glass layer was left. The sand core layer was removed from the inside after the core had been decorated and cooled.

Dominik Labino in Ohio, USA has been one of the most successful glass artists to reproduce core-formed vessels. Two examples of his work can be seen on exhibition at the Pilkington Glass Museum in St Helens. There have

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<sup>1</sup> “*The dipping of a core into molten glass is considered to be most unlikely as there seems little chance that the Egyptians would have been able to produce a core which would have been able to stand being dipped into a crucible of hot glass whilst remaining sufficiently friable to be removed later. One aspect of this theory which is often quoted is that it would not have been possible because the Egyptians did not make their own glass. Whilst this seems likely to be true, they certainly re-melted imported glass chunks in small crucibles and in the unlikely even of a suitable core and large crucibles than those which have been found being available it would have been possible to dip a core into hot glass. It is thought that the Egyptians at that time relied on re-working imported chunks and frits from what is now the state of Israel or from areas in or around Syria. There is certainly plenty of evidence of trade in blocks of glass with upper Syria. As any practicing glassworker will know, it is a standard operation whereby small pieces of coloured glass are heated sufficiently to be picked up on a punty iron and after further heating in a glory hole, used for trailing around another form. As this method would need nothing more sophisticated than an open fire, possibly with some kind of enhanced draught, it seems the most likely method of trailing glass around a suitable core in ancient Egypt.*

*As a result of a comprehensive search for a core-formed vessel with sufficient of the core intact to provide an analysis, one was found which revealed a two-layer system: the outer layer being largely composed of limestone fragments and the inner of what seemed to be a mixture of sane, clay and vegetable matter which probably came from dung. It is possible that a variety of techniques were employed in different locations over many years to make cored vessels but on current evidence the most probable method was that of trailing hot glass around a core. As the outer surface of these vessels is usually smooth, it also likely that after trailing, they were combed and then smoothed on a flat stone or on a wet wooden paddle. (Bray, Charles 2001, 86 second edition *The Dictionary of Glass: Materials & Techniques*).*

been several attempts by other glass artists to achieve a reproduction of core formed vessels. The results of Labino's researches and experiments were published in the Journal for Glass Studies, Corning, 1966 but in order to avoid the possibility of the production of fakes, the composition of Labino's core was kept a secret.

### **5.3.3(1) Core making Scoping experiment 1.**

Materials such as cow manure, kangaroo droppings, and emu droppings were made up into mixtures containing clay and sand and moulded onto mandrels and allowed to dry slowly. Once dry the made up cores were coated with bead-making release slip then fired up to 980 degrees Celsius. However, the fired cores proved to be very friable and usually disintegrated when my collaborating colleague attempted to wind threads of glass around the core while using a Bead-making torch and implements. A rumour passing around the glass-making community claimed that a glass artist giving a workshop at Pilchuk, Seattle, USA had used steel-wool wound around a mandrel that was then dipped it into creamy slip release. This core-making innovation was a modern approach to an old problem.

### **5.3.3(2) Scoping steel-wool core experiment 2.**

My collaborating colleague and I wound some steel-wool onto mandrels then dipped the mandrels into a bead-making releasing slip as a scoping experiment. The steel-wool core was allowed to dry before an attempt to trail a thread of molten glass around it. This alternative core-making experimental method proved to be much more successful than the ancient dung core method in that the core did not disintegrate during the trailing of molten glass.

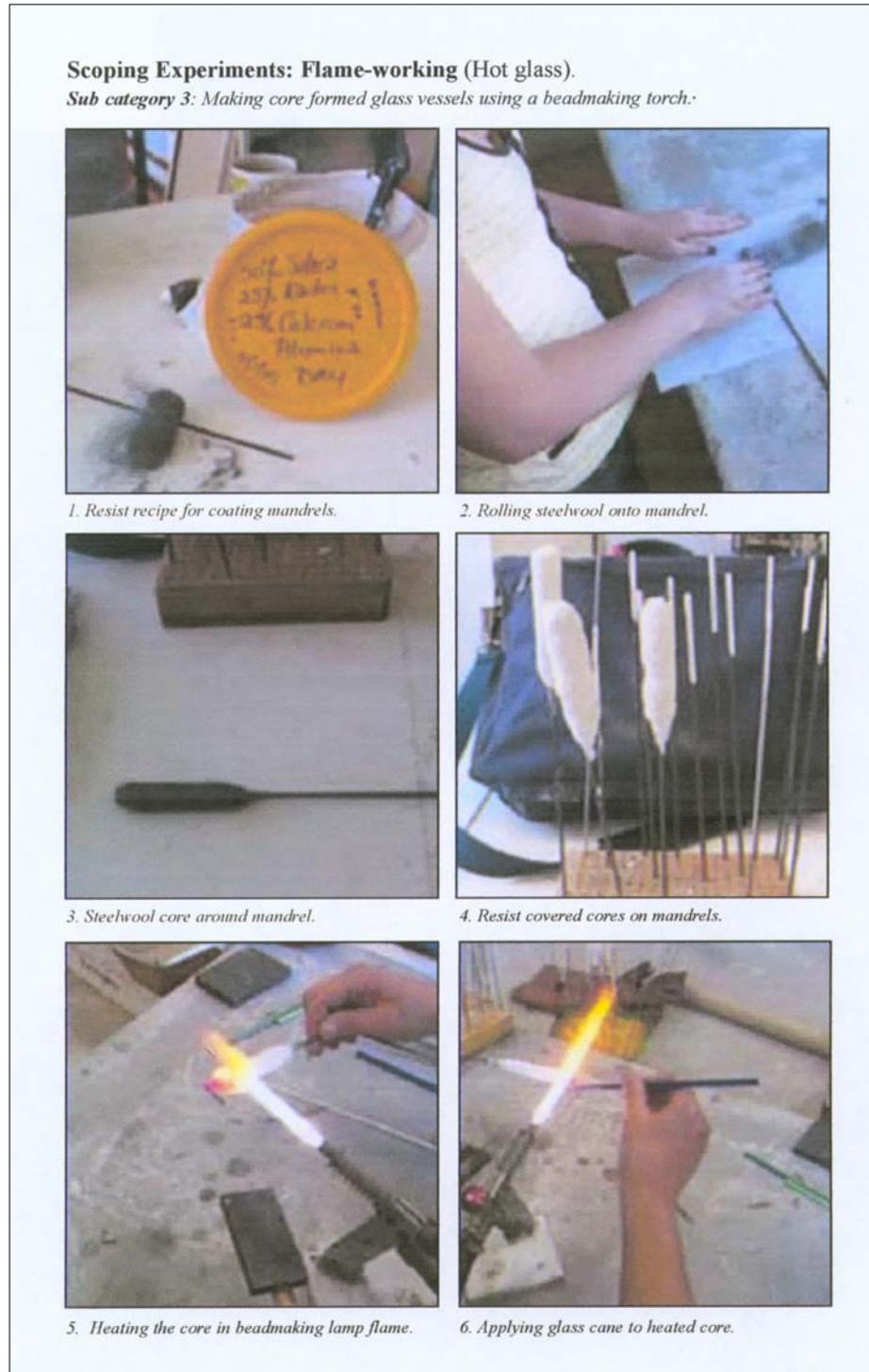
#### **Conclusion:**

My collaborating colleague, an experienced bead-maker found that the application of fine glass trails to the core by melting the tip of a pre-formed thin rod and attaching it to the vessel's body then turning the vessel to wind the glass rod around it very difficult to coat the entire core. Photosensitive glass

incorporation had not at this stage been attempted. It was at this stage that a miniature furnace to provide a supply of molten glass to cover the core would have been advantageous. My intention had been to cover the core with molten glass from the miniature furnace then roll the hot core covered glass over pre-heated photosensitive glass chips before returning the core to the bead-making torch for flashing. I planned to anneal the core with its rod still attached before exposing it to ultraviolet light on a rotating wheel in the light box. The rod would then be removed under safe photographic red light conditions. I planned to clean the core out of the vessel before placing the vessel in a digitally controlled kiln for the heat development state. The Generation 3 Bead-maker by Dudley Giberson (1991) had been my inspiration when I designed my miniature propane gas fired furnace with bead making and core forming facilities.

**Figure 1(a).**

Making the scoping core forming mandrels.



**Figure 1(b).**

Making the coreformed vessels using a bead-making torch.

**Scoping Experiments:Flame-working (Hot glass).**

*Sub category 3: Making core formed glass vessels using a Beadmaking torch.*



7. Tip of core vessel.



8. Heating tip in the torch flame,



9. Pre-marvering tip of core vessel.



10. Marvering tip of core vessel.



11. Working with tweezers.



12. Tweezers pulling base of core vessel.

### **5.3.3a. Core formed vessels Scoping Experiment A.**

#### **Process/activity**

Once my miniature furnace had been built, I made three scoping core vessels using the steel wool technique. The mandrels were heated in an annealing kiln before being dipped into the white opaque Gaffer #101 molten glass in the furnace crucible. The hot glass covered mandrels were then marvered on a stainless steel polished plate, returned to the furnace for heating before rolling them onto hot chips of photosensitive glass that had been heating in the annealing kiln. The workshop lights were dimmed so that the latent ultraviolet light would not affect the photosensitive glass covered core while it was being re-heated in the bead-making furnace. The photosensitive covered core vessels were marvered until the surface was smooth before being placed with their attached mandrel, in the annealing kiln. After annealing, the core-vessels were exposed to ultraviolet light in the light box for 40 minutes at the base of the core, 10 minutes in the middle of the core and 60 minutes at the tip of the core-vessel then heat developed at 550 degrees Celsius in a digitally controlled electric kiln for 181 minutes.

A scoping test was carried out using three photosensitive core-formed beads, made in the miniature furnace. This scoping test was aimed at the heat development stage. Each photosensitive bead was placed with its mandrel intact in a specially marked kiln and fired at the same temperature for the same length of time. The results showed that kilns G1 and G3 were producing under-fired photosensitive cores. Kiln G2 results were correctly fired. This observation was based on the results of the bead-making experiments in Scoping experiment F.

#### **Conclusion:**

I decided that I would need a great deal of time learning the technical skills of core forming a vessel and was satisfied that it was possible for photosensitive glass to be incorporated into this ancient technique provided the glass-maker was an expert at making core formed vessels.

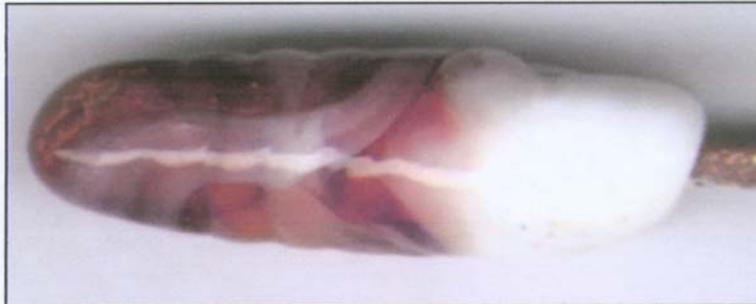
**Figure 2.** Experiment A.

**Scoping Experiments: Flame-working (Hot-glass)**

*Sub category 3: Corformed vessels*

**Scoping Experiment:** *Three mini furnace made Photosensitive Core Vessels*

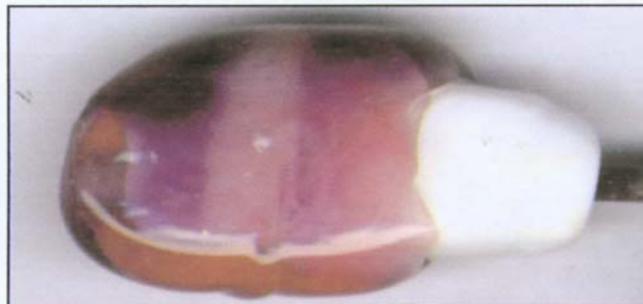
*Three photosensitive glass core vessels were made using the crucible in the miniature furnace. Controlled exposure to ultra-violet light was followed by controlled heat developed in three different electric kilns for the same length of time under digitally controlled conditions.*



*Kiln No: G1. Heat developed @550 deg Celsius for 181 minutes  
Exposed to ultra-violet light for 40 minutes at base of core vessel, 10  
minutes at middle and 60 minutes at tip of vessel.*



*Kiln No: G2. Heat developed @ 550 deg Celsius for 181 minutes.  
Exposed to ultra-violet light for 40 minutes at base of core vessel, 10  
minutes at middle of vessel and 60 minutes at tip of vessel.*



*Kiln No: G3. Heat developed @ .550 deg Celsius for 181 minutes  
Exposed to ultra-violet light for 40 minutes at base of vessel, 10 mins  
at middle of vessel and 60 minutes at tip of core vessel.*

## **References**

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## **Appendix Biv (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study Four: Kiln casting/kiln formed glass**

##### **Sub-category 5.4.1. Kiln casting/slumping**

##### **Overview of sub-category: Kiln casting/slumping**

Kiln casting/slumping are traditional warm glass techniques. These techniques require an understanding of warm glass principles. Kiln casting contains many of the elements of fusing and slumping but is generally more complicated.

Kiln casting is general terms that refer to placing pieces of glass in a mould at room temperature, then putting the mould in an electric kiln and heating it to a defined temperature.

The kiln casting/slumping technique also includes an alternative casting method favoured by the Romans during the Augustan Age. It involved the sagging of a glass blank over or in a 'former' mould while in the kiln (Klein & Ward 1992, 22).

##### **ScopingCase study project aims**

My aim for scoping case study Four, kiln casting/slumping was through systematic experimentation how to find ways to incorporate photosensitive glass into the traditional techniques.

**My research questions (and specific hypothesis) that were applied to kiln casting/slumping**

- What methods can I apply to incorporate photosensitive glass into the traditional techniques of kiln casting/slumping?
- What would happen if I used re-cycled crushed photosensitive glass chips?
- What would occur if I used unfired chip or crushed photosensitive glass with the molten furnace glass before I poured it into the mould inside the kiln before firing the kiln?
- What would the result be if I pre-flamed a large chip of photosensitive glass in the glory hole on a punty then dipping it into the molten furnace glass before dripping the hot glass mixture into the mould inside the kiln?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping them into the furnace glass then pouring this mixture into the mould inside the kiln?
- How would I anneal the cast/slumped photosensitive glass experiments?
- How would I store the cast/slumped photosensitive glass experiments?

**Process (standard applications) and technical skills required for Kiln casting/slumping**

**Kiln casting** involves the placing of glass frit or particles on top of a mould to form a bas-relief or plaque; this is a simple and effective method.

The various steps involved in kilns casting depend upon the particular type of casting required. They include model creation and material selection such as clay, wax or resin for making the model. Selecting the materials for making the mould are important, then the preparation of the mould. Moulds can be made using silica and Plaster of Paris in a fifty-fifty ratio, and then mixed with a specified amount of water. Mould making is often complicated and it is important that the type of mould suits the type of glass-work being attempted.

In most kilns casting the glass is totally encased inside the mould. Kiln casting can be done with pieces of glass of just about any size, ranging from frit to large chunks that barely fit in the kiln (Walker, B. 1999-2006). Firing the mould containing the glass-work needs specially formulated firing schedules suited to the size of the mould and the amount of glass being fired. Annealing is one of the most critical stages in working with molten glass. It is the process of slow-cooling the mould and can sometimes take a few days. Laboratory research and computer technology have taken some of the guesswork out of the time and temperature calculations needed to anneal a specific glass object. It is far better to over-anneal an object than to under-anneal one because the under-anneal glass will develop cracks or even break apart sometimes taking years to do crack or shatter (Kohler 1998, 55).

**Detailed questions to be asked by myself, the investigator for sub-category 5.4.1 of Case Study Four. Kiln casting/slumping glass**

(Prompts concerning the information that has to be gathered by the investigator).

- In what ways could I prepare the photosensitive glass for incorporation into the kiln casting/fusing technique?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was kiln casting/slumping?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before poured it into the mould.
- What would happened if I rolled my gather of furnace glass using a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before pouring the mixture into the mould?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before pouring the mixture into the mould?

- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before pouring it into the mould?
- How would I safely store the kiln cast/slumped photosensitive glass experiments prior to exposing them to ultra violet light?
- What annealing requirements are there for kiln cast/slumped photosensitive glass?

**Process (Standard applications) and technical skills required for sub-category 5.4.1 of Case Study Four. Kiln casting/slumping glass**

The steps taken in kiln casting may vary depending on the specific kind of casting but generally contain the following steps (Walker, B.1999-2006):

- The creation of a mould and the selection of mould materials such as clay, wax, metal, silica/plaster of Paris.
- The filling the mould with glass frit or chunks before firing the casting.
- Annealing and cooling the cast glass piece then removing and cleaning the cast piece.

The five steps taken in the kiln slumping process are:

- The heating up the glass in or over a mould. Heating the glass up to slumping temperature involves placing the glass on or over a prepared kiln mould inside the kiln.<sup>1</sup>
- Soaking the glass, this phase is concerned with soaking the glass at a particular temperature for a certain length of time. Longer soaking times cause the glass to flatten out and take on the shape of the mould and looks smoother in appearance.

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<sup>1</sup> Heat the glass between 800 degrees Celsius and 1000 degrees Celsius (1472 degrees Fahrenheit to about 1832 degrees Fahrenheit) depending on the individual kiln. To avoid thermal shock allow the glass to heat up slowly. At around 525 degrees Celsius (977 degrees Fahrenheit), the glass will begin to soften and appear glossy. Once past this stage there should no longer be problems with thermal shock ( Walker, B. 1997).

- Cooling the glass<sup>2</sup>,
- Then annealing the glass.<sup>3</sup> It is important to anneal glass pieces by soaking at these temperatures for about 20 minutes then slowly drop the temperature from the annealing point.
- Another method of going through the annealing stage is by slowly cooling the glass. This method allows the glass to relieve the stress as it slowly cools off. This method can be used when the annealing point for a particular glass cannot be located.
- Cooling slowly drops the temperature through different ranges of annealing.

#### **Process/method for sub-category 5.4.1. Annealing**

The following method is referred to as a constant linear annealing or shotgun annealing. Cool the glass to room temperature. After the glass has gone through the annealing stage and the stress has been relieved, it is safe to turn off the kiln and allow it to cool naturally to room temperature. This process is more suitable for small pieces of glass. It is important for larger pieces of glass to continue to be allowed to cool down slowly as this will help with avoiding thermal shock. To avoid thermal shock it is wise to continually fire the kiln down slowly to cool it then to soak it or hold it at a defined temperature slowly until room temperature is reached. This process often takes days or weeks according to the size of the glass

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<sup>2</sup>This phase deals with the personal preference of the glass artist. Some glass artists 'crash' cool the slumped piece of glass by opening the door of the kiln to rapidly drop the temperature to about 593 Degree Celsius (1100 degrees Fahrenheit). The reason for quick cooling the glass is to avoid devitrification which often occurs at temperatures about 704 degrees Celsius (13000 degrees Fahrenheit). Other artists just turn off the kiln and allow the piece to cool down on its own (Walker, B. 1997).

<sup>3</sup> The annealing process beings once the piece has cooled down to between 538 degrees Celsius to 566 degrees Celsius ( 1000 -1050 degrees Fahrenheit).. Annealing the glass helps to relieve the stress that has built up inside the glass (Walker, B.1997).

It is important that records of the kiln firing schedules that were used are kept for possible repeats of the process and future reference.

**Slumping** can be defined as a process of heating glass until it bends to conform to a shape defined by the containing mould or by supporting wires or rods. At 600 degrees Celsius ordinary soda-lime glass will start to deform. If the glass is required to slump deeply and conform to a more complex shape, higher temperatures are required. Casting glass in a mould is carried out by heating both mould and glass together in a kiln until the glass assumes the form defined by the mould. There are many casting techniques and it is essential to find a suitable glass that will flow, release easily, resist devitrification and that has appropriate annealing data available for a good clean casting.

### **Scoping experiments to incorporate photosensitive glass into glass casting techniques**

Many scoping experiments were attempted.

Photosensitive glass chips of various sizes, crushed and powdered photosensitive glass were sprinkled on top of the surface of crushed soda lime glass which had been placed in a mould. Each mould containing a specific granule size of photosensitive glass chips was placed in a digitally controlled electric kiln and fired for 271 minutes at a temperature of 600 degrees Celsius. When annealed, the moulds were removed from the kiln under safe red light, the glass cleaned of any mould residue so that it would be ready for ultraviolet light exposure.

### **Results:**

Unfortunately, at this stage the fired cast glass in moulds turned out to consist of a variety of red colours, indicating that the photosensitive glass had been '*cooked*' and would not be able to benefit from ultraviolet light exposure for any length of time before being returned to the kiln for heat development.

**Conclusion:**

This scoping experiment I regarded as unsuccessful.

**Scoping experiments using pre-flamed photosensitive glass**

Further scoping experiments using pre-flamed photosensitive glass that had been broken up into chips of various sizes, crush and powdered were treated in the same manner as the scoping experiments using the *'unflamed'* photosensitive glass.

**Result:**

The *'unflamed'* results were disappointing in that the colours produced post ultraviolet light exposure and then heat developed at the temperature of 550 degrees Celsius ranged from bright red to dark liverish-red (haematone).

No attempt was made to expose the pre-flamed photosensitive glass scoping experiments to ultraviolet light then heat develop at the lower temperature.

**Conclusion:**

This judgment was based on the assumption that the original heating up of the kiln to a temperature that would melt the photosensitive glass in the mould was too high for any colour development other than red.

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## **Appendix Biv (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Four: Kiln casting/kiln forming glass**

**Sub-category 5.4.2:** Simple open-face casting/fusing using a triaxial blending system.

#### **Overview of sub-category: kiln casting/kiln fusing glass**

This scoping sub-category used a triaxial blending system to research simple open-face casting/fusing in attempt to incorporate photosensitive glass into the traditional technique know as Pate de Verre<sup>91</sup>. Kiln fusing is the melting of two or more compatible pieces of glass together in a kiln. When the glass pieces are heated the glass softens and as more heat is applied, they begin to melt together, flatten out and become one solid piece of glass.

#### **Scoping case study project aims**

By using a twenty-one glass triaxial blending system variations in colour, involving two compatible glasses with photosensitive glass were my basic reasons for attempting to develop a greater visual control and colour development.

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<sup>91</sup> Pate de Verre is sometimes used as a generic term for kiln casting but is actually referring to a very specialize kind of casting (Walker 1999).

**My research question (and specific hypothesis) that was applied to sub-category 5.4 2: Simple open face casting/fusing using a triaxial blending system.**

What methods can I apply to incorporate photosensitive glass into the traditional technique of Pate de Verre?

Questions asked were:

- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was kiln forming Pate de Verre?
- What would occur if I used unfired, chips or crushed photosensitive glass with the molten furnace glass before I crushed the mixture then placed it into the mould inside the kiln before firing the kiln?
- What would happen if I used photosensitive as a casing glass over an opaque glass before dipping them into the furnace glass then crushing this mixture when cold before placing the crushed mixture into the mould inside the kiln?
- How would I anneal the triaxial Pate de Verre photosensitive glass experiments?
- How would I store the triaxial Pate de Verre photosensitive glass experiments?

**Detailed questions to be asked by myself, the investigator for sub-category 5.4 2**

- In what ways could I prepare photosensitive glass for making Pate de Verre?
- What would happen if I used crushed photosensitive chips or powder when I was making Pate de Verre triaxials?
- What would occur if I used unfired chips or crushed photosensitive glass in the triaxial mix with the other two glasses?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda

lime furnace glass before cooling and then crushing the mixture before adding it to the triaxial mixture?

- What sizes should the crushed chips be when making up the triaxials?
- How would I grade the crushed sieved photosensitive glass pieces?
- How would I safely store the triaxial mixes for the experiments before to exposing them to ultra violet light?
- What annealing requirements for the triaxials?

### **Process (standard applications) and technical skills required for kiln formed/kiln cast glass**

#### **Designing the scoping experiments**

Calculations for the scoping experiments using Gaffer #80 photosensitive ruby glass, clear used Soda-lime glass from the furnace and Gaffer #101 Opalescent White glass were made using a triaxial blend.

**Calculator@<http://www.triaxialblend.com>** and the total gram amounts for the three glasses used were calculated.

**<http://triaxialblend.com/CalculatorResults.aspx>**

A twenty-one glass blend triangle rather than a six or ten blend triangle was selected so that the fraction of subtle change between each disk mixture would be a twenty percent or one fifth difference.

#### **Calculations**

The gram amounts for each glass being used in the scoping triaxial blend mixture was 350 grams. The total amount of 1050 grams for each triaxial blend was divided by twenty one for each disk in the experiment. This allowed 50 grams of percentage blend mixture for each disk. Two disks were required for each scoping ultraviolet light exposure and heat development temperature and time experiment. This calculation for the three scoping experiments therefore allowed 25 grams or half a teaspoon of blend mixture for each disk.

### **Selecting my experimental variables**

These three scoping experiments were controlled by the independent variables, the development temperature of 525 degrees Celsius, the ultra-violet light exposures and the time taken for the heat development. The dependent variables are the colour and intensity of the Pate de Verre disks.

Allison, O'Sullivan and Owen (1996, 7-29) state that in order to be able to predict an outcome in experimental research, some variables are controlled and some are manipulated. The key variables in experimental research are of two kinds – the independent variable and the dependent variable. The dependent variable is the phenomenon that appears, disappears or changes as the independent variable is applied.

### **Scoping experiments procedure**

#### **Method used:**

Half a teaspoon of each blend mixture was placed into a numbered silver muffin baking sleeve on a rotating turntable (potter's wheel head).

The first scoping experiment was exposed in the ultraviolet light-box for twenty minutes then heat developed at a temperature of 550 degrees Celsius for 180 minutes. Three more scoping triaxial experiments were heat developed at 525, 505 and 495 degrees Celsius at an ultraviolet exposure of 20 minutes for 180 minutes.

#### **Results:**

The textures resembled molten marble-like material and I suggest that the potential outcome of the scoping experiments would be in the domestic area of architecture. The grains of the blend have adhered together well forming a strong body.

#### **Conclusion:**

I concluded, based on the results of the four scoping triaxials that there were positive indications for further research. By using the triaxial blending and the line blending processes, a systematic experimental framework has been

achieved that will meet my objective of how much photosensitive glass is needed to develop weak colour, medium colour and strong colour and any other unknown special colour results. The temperature and time ranges for heat development in an electric digitally controlled kiln for any colour development. In addition, timed ultraviolet light exposure to the experiments will be explored with the control and the variable experiments.

**Figure 1.**

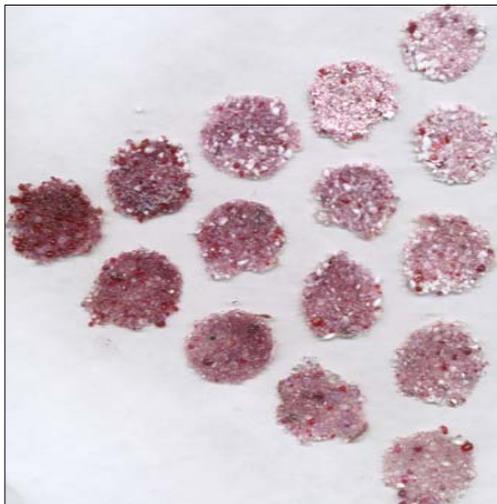
**5.4.2. First Scoping Triaxial experiments:**



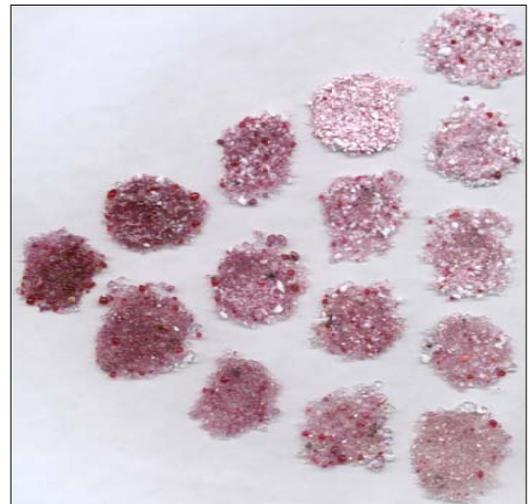
**Scoping Triaxial No: 5.**  
*UV exposure: 20 minutes*  
*Heat development: @ 550 degrees Celsius for 180 minutes.*  
**Colour development** shows reds, pink-reds, orange-reds, one orange, assorted pinks, cerise's, six blues, one violet and four mauves.



**Scoping Trail No: 19**  
*UV exposure: 20 minutes*  
*Heat development: @ 525 degrees Celsius for 180 minutes.*  
**Colour development** shows mainly reds, pinks, pink/reds, pink/oranges, six blues, mauves, one purple, two violets and two oranges amongst the pin/reds, red, cerise.



**Scoping Trail No: 31**  
*UV exposure: 20 minutes.*  
*Heat development: @ 505 degrees Celsius for 180 minutes.*  
**Colour development** shows ten blues, seven violets, five mauves, four purples, three oranges amongst a variety of pinks.



**Scoping Triaxial No: 46**  
*UV exposure: 20 minutes.*  
*Heat development: @ 495 degrees Celsius for 180 minutes.*  
**Colour development** shows fifteen mauves, eleven blues, eight violets, two purples and two oranges.

**Discussion**

The illustrated examples of the scoping triaxials shown above were all exposed to ultraviolet light for 20 minutes then heat developed in a HARCO controlled electric kiln for 180 minutes. The heat development temperatures were tested at 550, 525, 505 and 495 degrees Celsius.

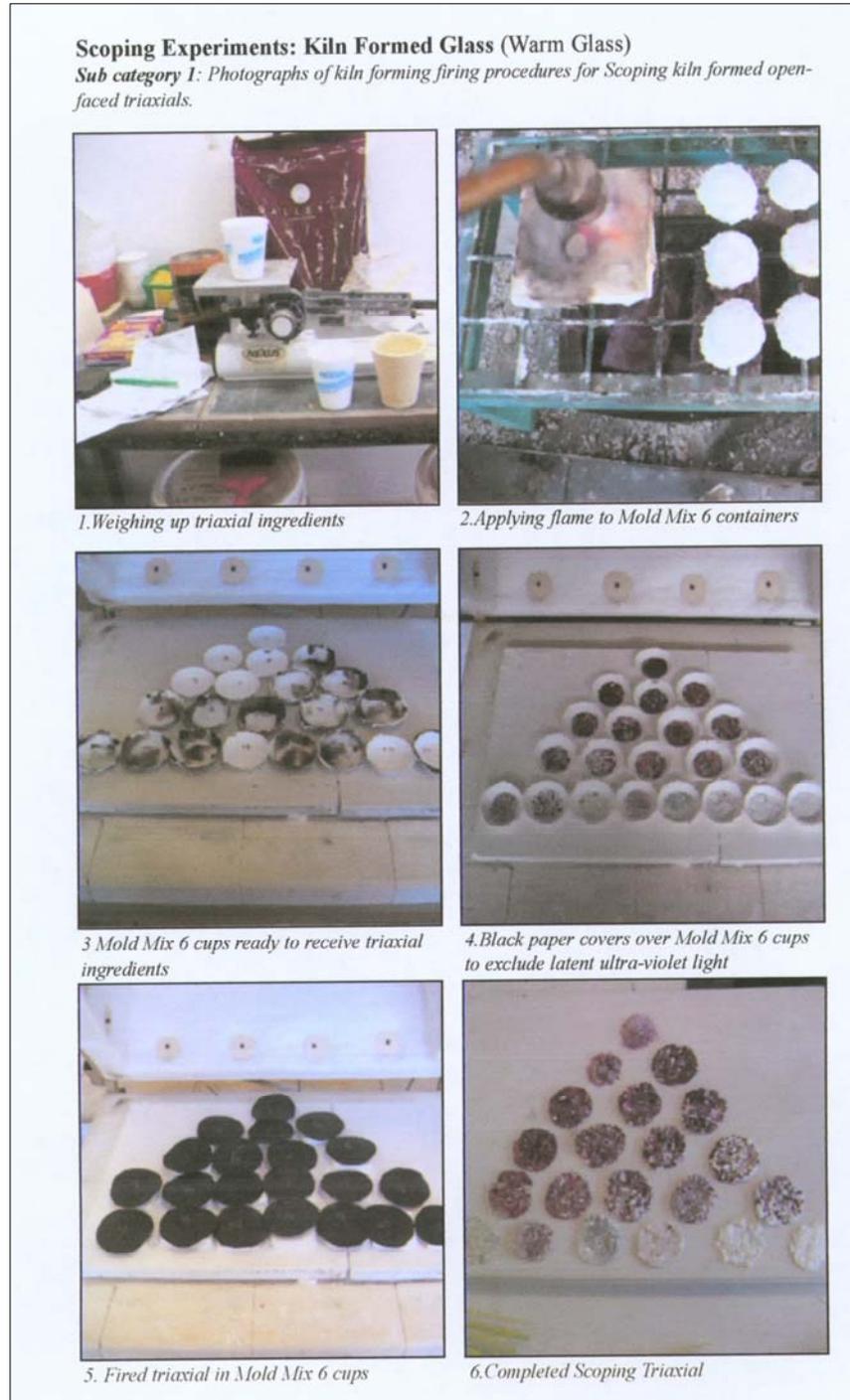
**Results:**

The grains of glass in the blend have adhered together well, forming a strong body of glass material. The colour range in each scoping triaxial indicated that the number of blues, mauves, violets, purples and oranges was based upon the development temperature of each triaxial.

**Conclusion:**

I concluded that the four scoping triaxials indicated that further research for a broader range of colour development using this system had potential towards an original contribution to glass art.

**Figure 2.**



### **Scoping experiments to incorporate photosensitive glass into kiln casting/kiln forming techniques**

By using the triaxial blending and the line blending processes, a systematic experimental framework has been achieved that will meet my objective of how much photosensitive glass was needed to develop weak colour, medium colour and strong colour and any other unknown special colour results using selected temperature and times for heat development in an electric digitally controlled kiln. In addition, timed ultraviolet light exposure to the experiments was explored with the control and the variable experiments.

### **References**

Allison, O'Sullivan and Owen (1996). *Research Skills for Students: The methods of research*. London: Kogan Page.

Open-face kiln forming (triaxials)

Calculator@<http://www.triaxialblend.com> and the total gram amounts for the three glasses used were calculated.

<http://triaxialblend.com/CalculatorResults.aspx>

(accessed March 3, 2008).

Walker, B. 1999. *Contemporary Warm Glass: A Guide to Fusing, Slumping and Related Kiln-Forming Techniques*. Clemmons, NC 27012. USA: Four Corners International, Inc.

## **Appendix Biv (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Four: Kiln casting/kiln forming glass**

**Sub-category 5.4.2:** Simple open-face casting/fusing using a triaxial blending system.

#### **Overview of sub-category: kiln casting/kiln fusing glass**

This scoping sub-category used a triaxial blending system to research simple open-face casting/fusing in attempt to incorporate photosensitive glass into the traditional technique know as Pate de Verre<sup>91</sup>. Kiln fusing is the melting of two or more compatible pieces of glass together in a kiln. When the glass pieces are heated the glass softens and as more heat is applied, they begin to melt together, flatten out and become one solid piece of glass.

#### **Scoping case study project aims**

By using a twenty-one glass triaxial blending system variations in colour, involving two compatible glasses with photosensitive glass were my basic reasons for attempting to develop a greater visual control and colour development.

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<sup>91</sup> Pate de Verre is sometimes used as a generic term for kiln casting but is actually referring to a very specialize kind of casting (Walker 1999).

**My research question (and specific hypothesis) that was applied to sub-category 5.4 2: Simple open face casting/fusing using a triaxial blending system.**

What methods can I apply to incorporate photosensitive glass into the traditional technique of Pate de Verre?

Questions asked were:

- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was kiln forming Pate de Verre?
- What would occur if I used unfired, chips or crushed photosensitive glass with the molten furnace glass before I crushed the mixture then placed it into the mould inside the kiln before firing the kiln?
- What would happen if I used photosensitive as a casing glass over an opaque glass before dipping them into the furnace glass then crushing this mixture when cold before placing the crushed mixture into the mould inside the kiln?
- How would I anneal the triaxial Pate de Verre photosensitive glass experiments?
- How would I store the triaxial Pate de Verre photosensitive glass experiments?

**Detailed questions to be asked by myself, the investigator for sub-category 5.4 2**

- In what ways could I prepare photosensitive glass for making Pate de Verre?
- What would happen if I used crushed photosensitive chips or powder when I was making Pate de Verre triaxials?
- What would occur if I used unfired chips or crushed photosensitive glass in the triaxial mix with the other two glasses?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda

lime furnace glass before cooling and then crushing the mixture before adding it to the triaxial mixture?

- What sizes should the crushed chips be when making up the triaxials?
- How would I grade the crushed sieved photosensitive glass pieces?
- How would I safely store the triaxial mixes for the experiments before to exposing them to ultra violet light?
- What annealing requirements for the triaxials?

### **Process (standard applications) and technical skills required for kiln formed/kiln cast glass**

#### **Designing the scoping experiments**

Calculations for the scoping experiments using Gaffer #80 photosensitive ruby glass, clear used Soda-lime glass from the furnace and Gaffer #101 Opalescent White glass were made using a triaxial blend.

**Calculator@<http://www.triaxialblend.com>** and the total gram amounts for the three glasses used were calculated.

**<http://triaxialblend.com/CalculatorResults.aspx>**

A twenty-one glass blend triangle rather than a six or ten blend triangle was selected so that the fraction of subtle change between each disk mixture would be a twenty percent or one fifth difference.

#### **Calculations**

The gram amounts for each glass being used in the scoping triaxial blend mixture was 350 grams. The total amount of 1050 grams for each triaxial blend was divided by twenty one for each disk in the experiment. This allowed 50 grams of percentage blend mixture for each disk. Two disks were required for each scoping ultraviolet light exposure and heat development temperature and time experiment. This calculation for the three scoping experiments therefore allowed 25 grams or half a teaspoon of blend mixture for each disk.

### **Selecting my experimental variables**

These three scoping experiments were controlled by the independent variables, the development temperature of 525 degrees Celsius, the ultra-violet light exposures and the time taken for the heat development. The dependent variables are the colour and intensity of the Pate de Verre disks.

Allison, O'Sullivan and Owen (1996, 7-29) state that in order to be able to predict an outcome in experimental research, some variables are controlled and some are manipulated. The key variables in experimental research are of two kinds – the independent variable and the dependent variable. The dependent variable is the phenomenon that appears, disappears or changes as the independent variable is applied.

### **Scoping experiments procedure**

#### **Method used:**

Half a teaspoon of each blend mixture was placed into a numbered silver muffin baking sleeve on a rotating turntable (potter's wheel head).

The first scoping experiment was exposed in the ultraviolet light-box for twenty minutes then heat developed at a temperature of 550 degrees Celsius for 180 minutes. Three more scoping triaxial experiments were heat developed at 525, 505 and 495 degrees Celsius at an ultraviolet exposure of 20 minutes for 180 minutes.

#### **Results:**

The textures resembled molten marble-like material and I suggest that the potential outcome of the scoping experiments would be in the domestic area of architecture. The grains of the blend have adhered together well forming a strong body.

#### **Conclusion:**

I concluded, based on the results of the four scoping triaxials that there were positive indications for further research. By using the triaxial blending and the line blending processes, a systematic experimental framework has been

achieved that will meet my objective of how much photosensitive glass is needed to develop weak colour, medium colour and strong colour and any other unknown special colour results. The temperature and time ranges for heat development in an electric digitally controlled kiln for any colour development. In addition, timed ultraviolet light exposure to the experiments will be explored with the control and the variable experiments.

**Figure 1.**

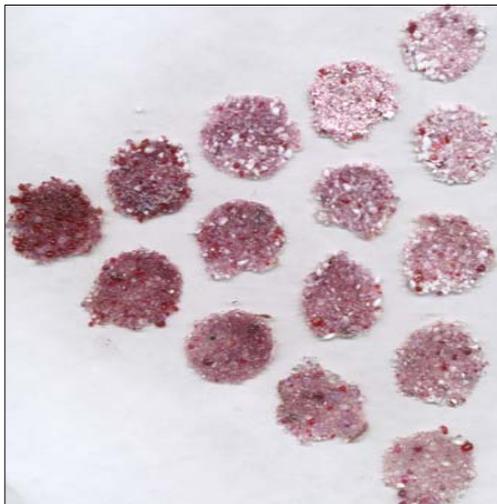
**5.4.2. First Scoping Triaxial experiments:**



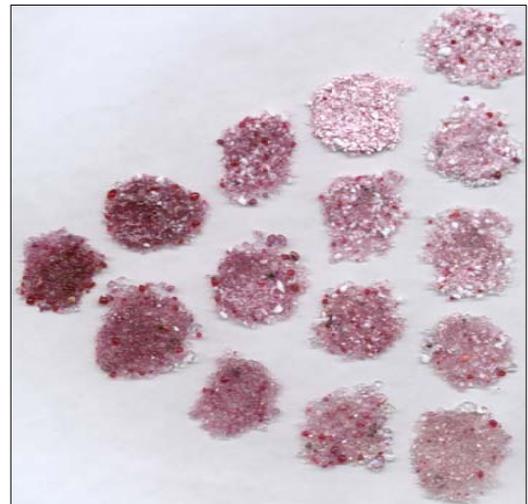
**Scoping Triaxial No: 5.**  
*UV exposure: 20 minutes*  
*Heat development: @ 550 degrees Celsius for 180 minutes.*  
**Colour development** shows reds, pink-reds, orange-reds, one orange, assorted pinks, cerise's, six blues, one violet and four mauves.



**Scoping Trail No: 19**  
*UV exposure: 20 minutes*  
*Heat development: @ 525 degrees Celsius for 180 minutes.*  
**Colour development** shows mainly reds, pinks, pink/reds, pink/oranges, six blues, mauves, one purple, two violets and two oranges amongst the pin/reds, red, cerise.



**Scoping Trail No: 31**  
*UV exposure: 20 minutes.*  
*Heat development: @ 505 degrees Celsius for 180 minutes.*  
**Colour development** shows ten blues, seven violets, five mauves, four purples, three oranges amongst a variety of pinks.



**Scoping Triaxial No: 46**  
*UV exposure: 20 minutes.*  
*Heat development: @ 495 degrees Celsius for 180 minutes.*  
**Colour development** shows fifteen mauves, eleven blues, eight violets, two purples and two oranges.

**Discussion**

The illustrated examples of the scoping triaxials shown above were all exposed to ultraviolet light for 20 minutes then heat developed in a HARCO controlled electric kiln for 180 minutes. The heat development temperatures were tested at 550, 525, 505 and 495 degrees Celsius.

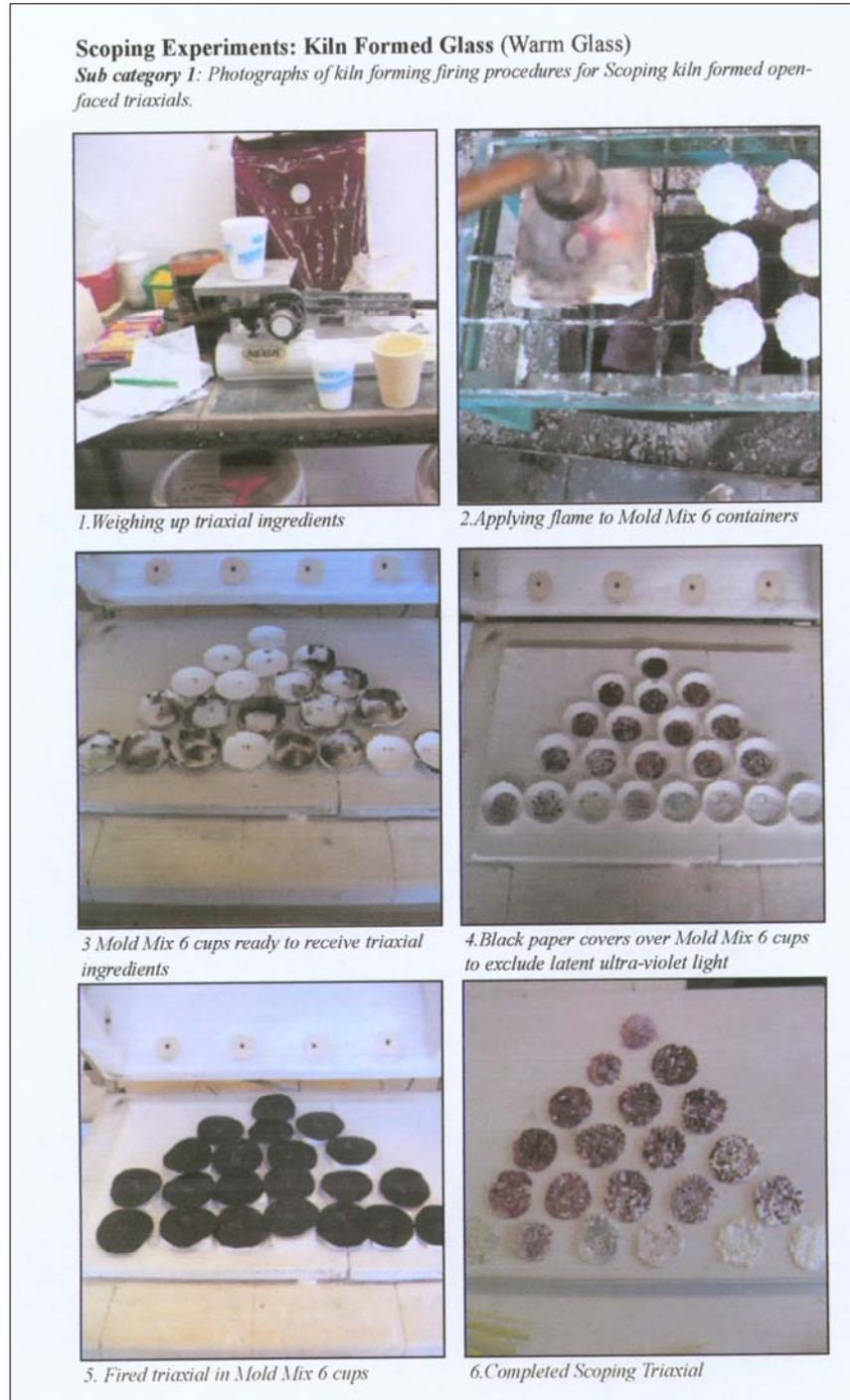
**Results:**

The grains of glass in the blend have adhered together well, forming a strong body of glass material. The colour range in each scoping triaxial indicated that the number of blues, mauves, violets, purples and oranges was based upon the development temperature of each triaxial.

**Conclusion:**

I concluded that the four scoping triaxials indicated that further research for a broader range of colour development using this system had potential towards an original contribution to glass art.

**Figure 2.**



### **Scoping experiments to incorporate photosensitive glass into kiln casting/kiln forming techniques**

By using the triaxial blending and the line blending processes, a systematic experimental framework has been achieved that will meet my objective of how much photosensitive glass was needed to develop weak colour, medium colour and strong colour and any other unknown special colour results using selected temperature and times for heat development in an electric digitally controlled kiln. In addition, timed ultraviolet light exposure to the experiments was explored with the control and the variable experiments.

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Open-face kiln forming (triaxials)

Calculator@<http://www.triaxialblend.com> and the total gram amounts for the three glasses used were calculated.

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(accessed March 3, 2008).

Walker, B. 1999. *Contemporary Warm Glass: A Guide to Fusing, Slumping and Related Kiln-Forming Techniques*. Clemmons, NC 27012. USA: Four Corners International, Inc.

## **Appendix Bv (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study Five: Furnace casting (Hot glass)**

##### **Sub-category 5.5.1. Sand Casting**

##### **Overview of sub-category: Sand casting**

Sand casting is a simple and direct method of pouring molten glass into a special sand to produce sculptural forms.

##### **Scoping Case Study project aims**

My aims were to find ways through systemic experimentation how to incorporate photosensitive glass into the ancient technique of sand casting so that design elements could be placed within the glass body using ultraviolet light exposure and heat development to produce a desired colour range.

##### **My research questions (and specific hypothesis) that were applied to sand casting**

- What methods can I apply to incorporate photosensitive glass into the traditional technique of casting glass directly from the furnace?
- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was casting directly from the furnace?

- What would the result be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty before dipping it into the molten furnace glass then pouring the mixture into a mould?
- How would I store the sand-cast photosensitive glass experiments?
- What is the optimum way of using photosensitive glass in the direct sand casting method?
- What annealing requirements are there for cast photosensitive glass?

## **Process (standard application) and technical skills**

### **Sub-category 5.5.1: Sand Casting**

#### **Method:**

This special sand is known as Olivine-sand or foundry sand and is mixed with 7% – 10% Bentonite clay and water this helps to hold the sand together, before being sifted into a box so that it will hold an impression made by an object. Once the impression has been made into the Olivine sand, the sand is compressed around the object before removing it carefully. In order to get a clear glass cast of the impression the Olivine sand has to be carbonized by using an acetylene torch to make black soot. This carbonization acts as a mould release and does not allow grains of sand to adhere to the glass being cast<sup>1</sup>. Molten glass from the furnace is then poured into the impression in the Olivine sand using a ladle or scoop made especially for the purpose of handling molten furnace glass. The temperature of the casting glass from the furnace is about 1200 degrees Celsius (2,220 degrees Fahrenheit) and has a ‘*slippery*’ consistency. It glows orange in colour as it comes out of the furnace in the ladle and into the sand impression. The ribbon of glass from the pouring ladle to the mould can be cut with a special pair of shears so as to neaten up the casting. A hot gas torch is used to burst any bubbles that arise from the

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<sup>1</sup> Some artists spray a mixture of sugar and water onto the surface of the impression and others use a mixture of molasses to create a carbonization barrier (Andrew Brott 2006) 18/04/2006). [http://www.glassartists.org/Gal17907\\_Glass\\_sand\\_casting.asp](http://www.glassartists.org/Gal17907_Glass_sand_casting.asp) 29/04/2009. Some artists spray a thin layer of carbon in the form of fine powdered or liquid graphite or fine icing sugar onto the surface of the sand to a clean release (Bray 2001,210).

pour when in the mould. It is important to evenly heat the edges or any narrow sections of the hot cast impression using a gas torch while it slowly cools. The method of venting the cast glass is accomplished by the use of sticks of wood that are inserted into the Olivine sand around the cast to release steam while it is cooling. Once it has cooled down sufficiently to keep its shape, the sand cast impression still containing a jacket of sand is carefully and quickly removed by sliding it onto a wooden board into the preheated annealing kiln. The newly created cast glass impression needs to be kept in the annealing kiln for several days depending on its thickness while the temperature gradually decreases in a cycle designed to release stress inside the cast glass.

**Detailed questions to be asked by myself, the investigator for scoping Case study Five, sub-category 5.5.1 Sand Casting**

- In what ways could I prepare the photosensitive glass for incorporation into the hot glass furnace casting technique?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was casting directly from the furnace?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before I cast it?
- What would happen if I rolled my gather of furnace glass using a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before casting the mixture into a metal mould?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before casting the mixture into a mould?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before pouring it into a mould?
- How would I safely store the furnace and sand cast photosensitive glass experiments before exposing them to ultra violet light?

- What annealing requirements are there for sand and mould cast photosensitive glass?

## **Scoping experiments to incorporate photosensitive glass into Sand Casting**

### **Scoping experiment 1. Sand Casting**

Chips of photosensitive glass were scattered onto the carbonized layer of the Olivene sand impression before the hot furnace glass was poured into the impression. The purpose of doing this was to allow the photosensitive glass to be picked up by the molten glass. Torches were used to burst any bubbles that arose from the cast and were then used to evenly cool down the cast while venting holes were inserted into the sand around the impression. The cast impression was then removed by sliding it onto a wooden board once it was cool enough to hold its shape. It was then placed on a shelf in a preheated anneal kiln to slowly cool down over several days so as to avoid thermal shock.

#### **Result:**

The result of the sand casting experiment was unsuccessful in that the only colour seen within the sculptural form was red as it came out of the annealing kiln.

#### **Conclusion:**

This sand casting experimental form did not undergo any exposure stage to ultraviolet light because the colour red indicated to me that the working temperature of the casting glass had been far too hot for the photosensitive glass. There was no point of putting the sculptural piece through the ultraviolet light exposure stage not the heat development stage as the only colour that would emerge would be the same red colour. The photosensitive glass had prematurely developed when the molten glass had been cast on top of the scattered chips.

## References

Brott, Andrew. 2006. *Sand casting*.

[http://www.glassartists.org/Gal17907\\_Glass\\_sand\\_casting.asp](http://www.glassartists.org/Gal17907_Glass_sand_casting.asp))

(accessed April 29, 2009).

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<http://www.glassnotes.com>

Stone, Graham. 1999-2000. *Firing Schedules for Glass: The Kiln Companion*.

20 Sydenham Street, Highett, Victoria 3190, Australia.

## **Appendix Bv (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Five: Furnace casting (Hot glass)**

**Sub-category 5.5.2:** Forcing hot molten glass into metal moulds

**Sub-category 5.5.3:** Casting into a variety of moulds

**Sub-category 5.5.4:** Sprinkling crushed photosensitive glass and/or powder into or onto the mould before casting.

#### **Overview of sub-categories 5.5.2 and 5.5.4: Casting directly into metal moulds**

Casting directly from the hot glass furnace is a simple and direct activity requiring team work. Blowing skills are not necessary but mould making skills are important.

#### **Scoping sub- categories 5.5.3 and 5.5.4 project aims**

My aims for the two sub-categories were to experiment with ways of incorporating photosensitive glass into these traditional techniques so that design elements could be placed within the glass body using ultraviolet light exposure and heat development to produce distinctive colours.

**My research questions (and specific hypothesis) that were applied** to casting into metal moulds were similar to those I asked for sub-category 5.5.1. Sand Casting.

**Process:**

This activity involves the casting of molten glass from the crucible of the glass furnace into a metal mold and then sprinkling crushed or powdered photosensitive glass into and/or onto the hot molten glass during the process.

**Temperature of casting glass in furnace**

The temperature of the casting glass in the furnace is about 1200 degrees Celsius (2,220 degrees Fahrenheit). The molten glass has a '*slippery*' consistency while it is being worked. It glows orange in colour as it comes out of the furnace and can be cut with special shears as it is poured from the ladle, punty or blowing iron directly into the mould.

**Detailed questions to be asked of myself, the investigator for scoping case study five, sub-category 5.5.2 and 5.5.4. Metal mould casting and Sub-category 5.5.3 Casting into a variety of moulds**

- In what ways could I prepare the photosensitive glass for incorporation into metal mould casting techniques?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was casting directly from the furnace?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before I cast it?
- What would happen if I rolled my gather of furnace glass using a punty into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before casting the mixture into a metal mould?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before casting the mixture into a mould?

- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before pouring it into a mould?
- How would I safely store the furnace and sand cast photosensitive glass experiments before exposing them to ultra violet light?
- What annealing requirements are there for sand and mould cast photosensitive glass?
- 

### **Scoping experiments**

#### **Process for the technique of casting into metal moulds**

A variety of metal moulds were made up by my collaborating colleagues for the following experiments.

**Combined sub-categories 5.5.2 & 5.5.4. Scoping experiment 1** Casting into a simple square shape metal mould.

#### **Method:**

A simple square metal mould was used. First the inside of the metal was sprayed lightly with WD40 to lubricate the metal. The metal ladle or ‘*scoop*’ (or large gather of furnace glass on a punty) was used to pick up molten glass from the furnace was pre sprayed with WD40 so that the hot glass would not stick to the bowl of the ladle. Powdered photosensitive glass was sprinkled directly into the bowl of the ladle so that it would melt into the hot glass before being poured into the mould. The idea was to have a decorative swirling of the photosensitive glass within the body of the moulded glass. Once the glass had cooled down sufficiently to hold its shape it was placed onto a wooden paddle board and placed on a shelf in the annealing kiln which had been preheated to 520 degrees Celsius (900 degrees Fahrenheit). Removal from the annealing kiln depended on the size of the piece. Some cast pieces take a few days to a week to anneal.

#### **Result:**

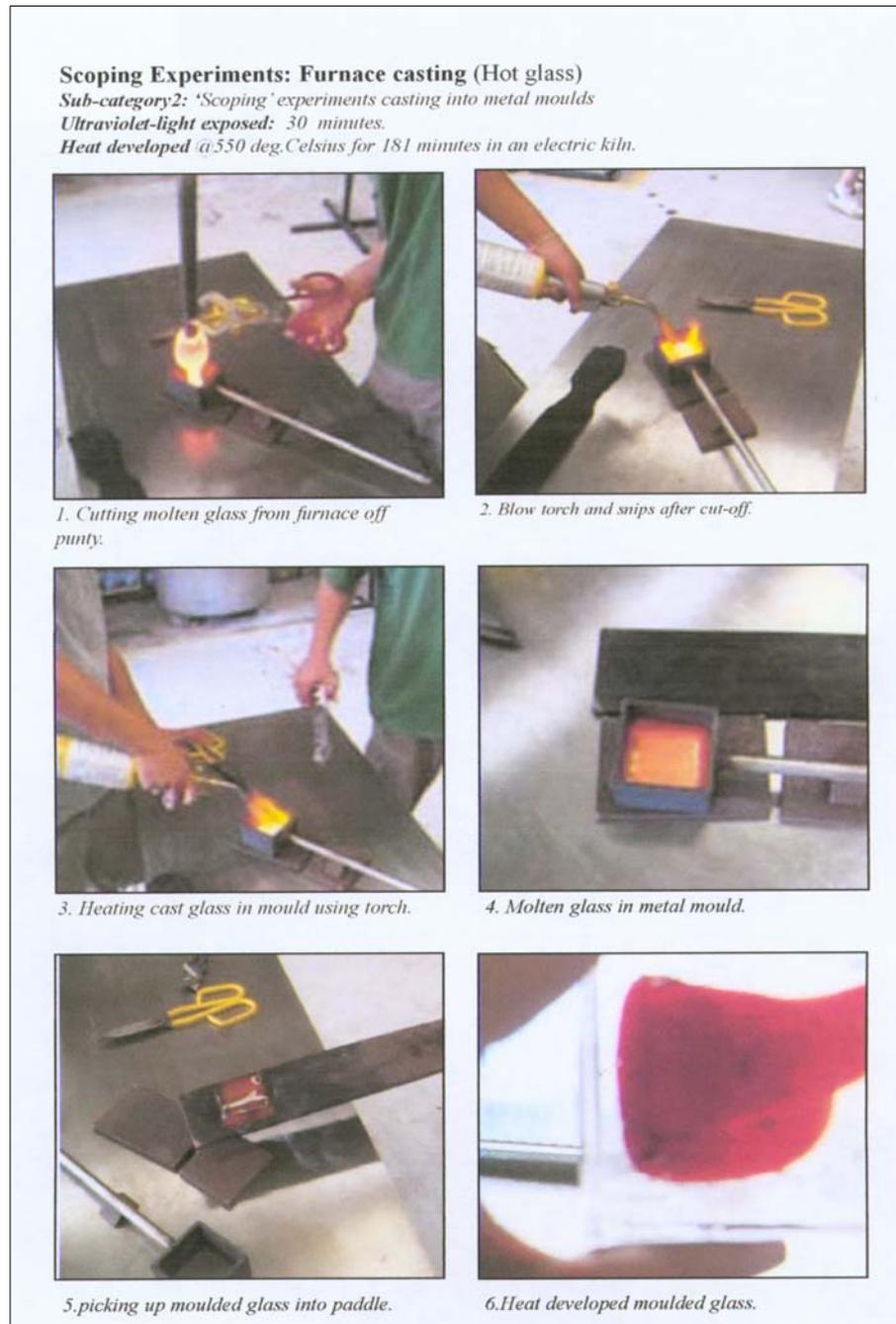
After annealing the square cast piece of glass was taken out of the kiln and then was then exposed to ultraviolet light for 30 minutes then heat developed at 550 degrees Celsius for 181 minutes.

**Conclusion:**

This experiment was partially successful in that it showed as a clear red with a distinctive random red colour image within the glass body.

**Figure 1.**

**Scoping experiment 1:**Sub-category 5.5.2: Forcing or casting glass into a simple metal mould.



**Scoping experiment 2a. Figure 2(a).**

**Sub-categories 5.5.2 and 5.5.4.** Double casting into a simple house-shaped metal mould.

**Method:**

A casting was made into a simple house-shaped metal mould applying a double layer of glass from the furnace.

**Process:**

After pouring the hot furnace glass into the metal mould using the metal ladle photosensitive glass powder was sprinkled on top of the hot glass and another scoop with the ladle of hot furnace glass was then poured on top of the photosensitive glass. The casting was annealed in a kiln for 48 hours. After annealing the double layer cast glass house was exposed to ultraviolet light for 20 minutes before being heat developed @ 550 degrees Celsius for 181 minutes.

**Results:**

The double layer of glass with the powdered photosensitive glass incorporate between the layers distorted and split exposing a layer of red coloured photosensitive glass.

**Conclusion:**

This experiment was unsuccessful.

**Figure 2(a).**

**Sub-categories 5.5.2 and 5.5.4.** Double casting into a simple house-shaped metal mould.



**Figure 2(b).**

**Sub-categories 5.5.2 and 5.5.4.** Close view of double casting into a simple house-shaped metal mould.



**Scoping experiment 2b.**

**Sub-categories 5.5.2 and 5.5.4.** Tripple casting.

**Method:**

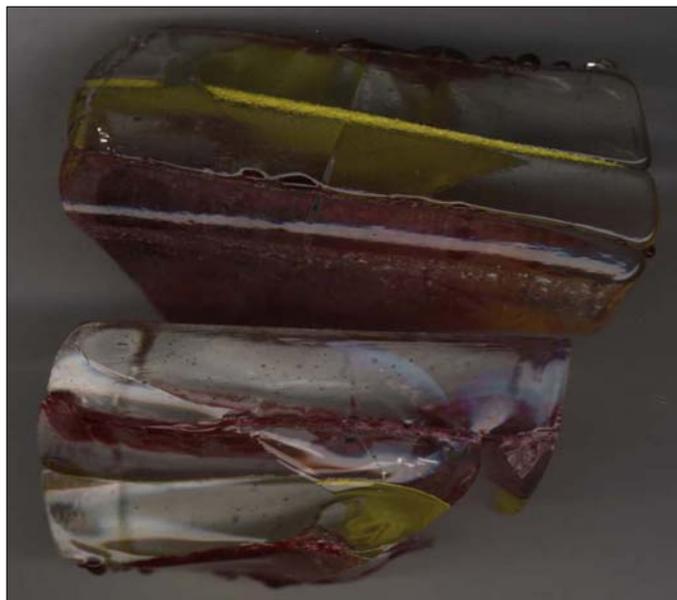
A tripple casting into a house shaped metal mould was attempted using powdered photosensitive glass between three layers of cast glass.

**Process:**

Two layers of sprinkled photosensitive glass were placed between three layers or poured molten layers of furnace glass in a metal mould. Once the glass in the moulds had cooled down enough to hold its shape the metal mould was removed and the shape containing the layers of photosensitive glass were slid onto a wooden board then loaded onto a kiln shelf in the annealing kiln that had been preheated to 520 degrees Celsius (900 degrees Fahrenheit).

**Figure 2(c).**

**Sub-categories 5.5.2 and 5.5.4.** Close view of tripple casting into a simple house shape metal mould.



**Results:**

The three layered glass house was exposed to ultraviolet light for 20 minutes then heat developed @ 550 degrees Celsius for 181 minutes.

The scattered colours within the glass house shape produced shades of dark-red between the glass layers. The cast glass house had distorted and split during heat development.

**Conclusion:**

Experiment 2b was a failure. Colour development showed two areas of dark red colour between the layers of cast molten glass. There was no range of colours.

**Scoping experiment 3.****Sub-categories 5.5.2 and 5.5.4. Casing into a cross shaped metal mould****Method:**

A casting was made into a cross-shaped metal mould using larger chips of photosensitive glass on to of the casting.

**Process:**

The hot furnace glass was scooped up from the crucible in the furnace using a metal scoop that looks like a large ladle on a long pipe. The glass was poured into a shaped metal mould that was placed on a metal plate. Once the assistant has trimmed the excess glass from the metal scoop, powdered or chips of various sizes of photosensitive glass were sprinkled onto the poured furnace glass in the mould. When the glass had cooled enough to hold its shape, the metal mould was removed and the hot piece was slid onto a wooden board then loaded onto a shelf in the annealing kiln that has been preheated to 520 degrees Celsius (900 degrees Fahrenheit).

**Result:**

After ultraviolet light exposure for 20 minutes and heat development @550 degrees Celsius globules of a darker red colour beaded on top of the cast cross above the bright medium red scattered powder that had been incorporated within the cast glass.

**Conclusion:**

This experiment was partially successful in that it produced two red colours due to the size of the photosensitive glass that had been scattered on top of the cast piece in the cross mould.

**Figure 3.**

**Sub-categories 5.5.2 and 5.5.4. Casing into a cross shaped metal mould.**



**Figure 4.**

**Scoping experiment 4.**

**Sub-category 5.5.3** Casting into a variety of moulds.



**Method:**

A piece of photosensitive glass was heated up in a kiln at 560 degrees Celsius until it had softened sufficiently to be picked up on a punty. It was then exposed to the heat of the glory hole until the photosensitive glass became molten enough to shape. It was then marved on the marvering table before being plunged into the furnace crucible. A gather of glass over the photosensitive glass was then marved before being returned for heating in the glory hole. The next step was to drop the molten glass on the punty into a plaster mould. Annealing took place in an electric kiln before the mould was broken away from the cast glass. The incorporated photosensitive cast piece was then heat exposed to ultraviolet light for 20 minutes and heat developed at 525 degrees Celsius for 120 minutes.

**Result:**

When held up to the light the naked eye can see the photosensitive section of the triangle to be a dark red-purple colour.

**Conclusion:**

This experiment was only partially successful in that the outer casing of molten glass separated from the photosensitive glass.

## **Appendix Bvi (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case study Six: Free blown glass and blowing a bubble into a mould (Hot glass)**

##### **Sub category 5.6.1. Free blowing glass**

##### **Overview of sub-category: Free blowing**

Free blowing is the process of introducing air into glass for the purpose of forming hollow ware (Bray 2001, 80). The free blowing of photosensitive glass was combined with traditional soda lime furnace glass using a blowing pipe. An assistant or a term of assistant is preferable.

##### **Scoping Case study project aims**

My aims were to assess and identify the amount of photosensitive glass needed to produce a colour wheel when making disks Crowns or Bullion that had been started in scoping case study One and to identify a suitable method of incorporating photosensitive glass when free blowing into a mould.

##### **My research question (and specific hypothesis) that was applied to all the sub-categories of case study six**

- What methods can I apply to incorporate photosensitive glass into the traditional technique of free blowing glass?

- What would happen if I used re-cycled crushed photosensitive glass chips or powder when I was blowing glass?
- What would occur if I used unfired, chips or crushed photosensitive glass with the molten furnace glass before blowing it?
- What would happen if I used photosensitive as a casing glass over an opaque glass before dipping them into the furnace glass then blowing it?
- How would I store the blown photosensitive glass experiments?
- What annealing requirements are there for blown photosensitive glass?

### **Process (standard application) and technical skills**

**Sub-category 5.6.1:** Free blowing photosensitive glass and casing it with soda lime furnace glass.

#### **Method:**

Free blown glass<sup>1</sup> [*Hot-glass*]. Blowing skills are essential and access to a hot glass furnace is essential. This is a difficult and complicated technique to master.

#### **Process:**

The technique of free-blowing glass requires the glass blower to gather a lump of hot glass on the end of a hollow metal tube, or blowpipe (paraison) then to inflate it to form a small bubble. The blowing pipe (paraison) is again inflated after dipping the bubble into the crucible of hot molten glass in the furnace.

The bubble is then shaped by the glass blower at a special bench then rolled in an open, cup-shaped wet wooden mould, returned to the glory hole for re-heating, then inflated again at the glass blower's bench, this procedure of returning the vessel to the glory-hole allows the glass blower to further shape the vessel using glass blower's tools until the desired shape is reached.

For additional finishing or for decorating, a pontil or punty with a small blob of hot glass from the furnace gathered on its end, is attached to the base of the

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<sup>1</sup> The process of introducing air into glass for the purpose of forming hollow ware (Bray 2001, 80).

vessel. The newly made glass vessel is then knocked-off the ‘paraison’ or blowpipe while still hot. The punty now holds the vessel allowing a rim to be formed at the ‘*knocked*’ off end. The vessel is returned to the glory hole many times during the decorating period so as to allow any decoration, handles, base-rings to be added before being knocked-off the punty and annealed in a kiln. Throughout this process, the vessel is rotated to prevent sagging. This technique was quickly transmitted throughout the provinces of the Roman Empire as it was relatively straight forward (Klein and Ward ( 1993, 11).

**Detailed questions to be asked by myself, the investigator for scoping Case study Six, sub-category 5.6.1. Free blowing and sub-category 5.6.2. Mould blowing photosensitive glass into a mould using a blowing pipe**

- In what ways could I prepare the photosensitive glass for incorporation into the hot glass free blowing technique?
- What would happen if I used re-cycled crushed photosensitive chips or powder when I was free blowing?
- What would occur if I used unfired chips or crushed photosensitive glass with the molten furnace glass before I blew it?
- What would happen if I rolled my gather of furnace glass using a blowing pipe into crushed photosensitive glass powder or chips then heated the mixture in the glory-hole before blowing the mixture into a metal mould?
- What would the results be if I pre-flamed a large chip of photosensitive glass in the glory-hole on a punty then dipped it into the molten soda lime furnace glass before blowing the mixture into a mould?
- What would happen if I used photosensitive glass as a casing glass over an opaque glass before dipping the mixture into the furnace glass before pouring it into a mould then blowing into it?
- How would I safely store the blown photosensitive glass experiments before to exposing them to ultra violet light?

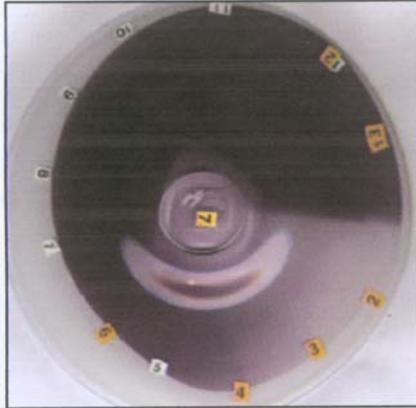
- What annealing requirements are there for blown photosensitive glass disks or mould blown glass?

**Figure 1.**  
**Scoping Experiments: Free Blowing (Hot glass).**

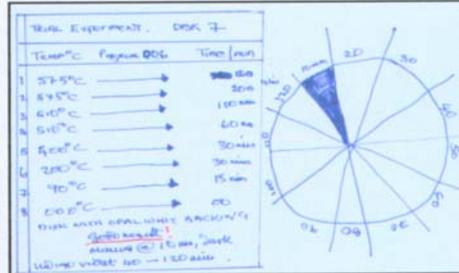
**Scoping Experiments: Free Blowing (Hot-glass)**

*Sub category 1: Blown glass bullion or glass disks.*

*Scoping Experiment: Trial Exposures of three photosensitive glass disks at three temperatures.*

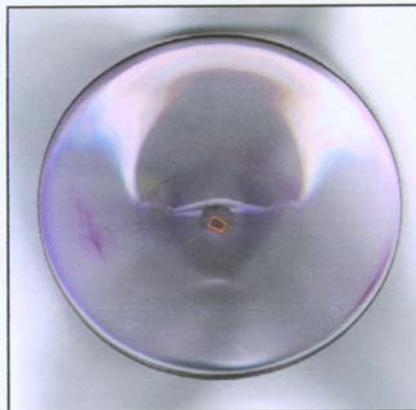


Disk 7: Photosensitive glass over Opal White glass

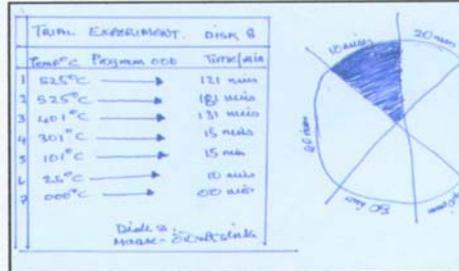


*'Trial Firing Schedule: 'Scoping' disk 7.*  
*Ultra violet light exposure: 10 minute intervals.*  
*Heat development: 575 deg C. for: 200 mins.*

*A good result. colour mauve @ 10 mins, dark indigo violet from 40-120 mins.*



Disk 8: Clear photosensitive glass

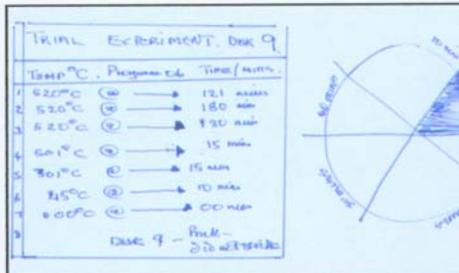


*'Trial Firing Schedule: 'Scoping' disk 8.*  
*Ultra violet light exposure: 10 mins intervals.*  
*Heat development: 525 deg C. for 180 mins.*

*Poor result: Colour pale mauve throughout - did not strike*



Disk 9: Clear photosensitive glass



*'Trial Firing Schedule: 'Scoping' disk 9.*  
*Ultra violet light exposure: 10 mins intervals.*  
*Heat development: 520 deg C. for: 180 mins.*

*Poor result: Colour - threads of pink. Did not strike.*

Scoping experiments to determine the amount of photosensitive glass needed to develop a colour wheel using time ultraviolet light exposure and timed heat developments at temperatures of 520, 525, 550 and 575 degrees Celsius in a digitally controlled kiln were the objective with sub-category 5.6.1. Kiln firing schedules were manipulated to achieve a positive outcome then a pilot experiment was made to refine the firing schedule procedure.

### **Scoping Experiment 1.**

Trial exposure of photosensitive glass disk 7.

Disk 7 consisted of photosensitive glass over Gaffer Opalescent White glass #101 encased in soda-lime glass. This disk was exposed under ultraviolet light at 10 minute intervals then heat developed for 200 minutes at a temperature of 575 degrees Celsius.

#### **Result:**

A good positive result of graded mauve from 10 minutes to deep purples at 40 minutes and dark indigo violet at 120 minutes was achieved.

#### **Conclusion:**

This experiment was successful.

### **Scoping Experiment 2.**

Trial exposures of photosensitive glass disk 8. This disk was composed of photosensitive glass encased in soda lime glass. Disk 8 was exposed under ultraviolet light at 10 minutes intervals up to 120 minutes then heat developed in an electric kiln for 180 minutes at a temperature of 525 degrees Celsius.

#### **Result and conclusion:**

A pale mauve colour with flecks of purple red was the '*strike*' result of the temperature being too low for heat development.

### **Scoping Experiment 3.**

Trial Exposures of photosensitive glass disk 9. This disk was exposed to ultraviolet light for 10 minutes intervals as done in disks 7 and 8. Disk 9 was heat developed in an electric kiln for 180 minutes at 520 degrees Celsius.

#### **Result:**

A very poor result was achieved there was practically no colour at all except for threads of pink within the glass body to indicate that it contained photosensitive glass.

#### **Conclusion:**

This photosensitive disk did not strike possible because of the low temperature of 520 degrees Celsius for timed heat development.

### **References**

Klein, D. and Ward, L. eds. 1993. (reprint) *The History of Glass*.

London. SE14YA. U: Black Cat imprint. Little, Brown and Company.

## **Appendix Bvii (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Five and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Scoping Case Study Seven: Acid etching/Acid embossing (Cold glass). Sub-category: 5.7.1.Acid etching/Acid embossing. Extremely hazardous!**

##### **Overview of Case Study 5.7.0**

Because the use of Hydrofluoric acid is a health hazard this scoping case study did not have any experiments.

##### **Scoping Case Study project aims**

I was interesting in discovering if it were possible to use photosensitive glass together with acid etching in an artistic environment. The scientific industry uses this acid etching process in manufacturing New Bragg Crating Positioner Platforms for fibre optic use<sup>105</sup>.

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<sup>105</sup> The Gale Group at NIST published a paper in their Journal of Research of the National Institute of Standards and Technology (2000) on the 'Technique Developed For Characterization Of Photosensitive Glass'. The group found that Ultraviolet light could induce a permanent change in the refractive index of a glass material. UV photosensitivity was found to be very useful in fabricating integrated optic and fiber Bragg grating devices. Fiber Bragg gratings are wavelength-selective reflectors that can be written into the core of optical fiber which is used in communication systems and also make excellent strain sensors that can be networked to obtain distributed strain measurements of large structures, such as bridge and ships.

**My research questions (and specific hypothesis) that were applied to the scoping case study**

- How can photosensitive glass be used together with the acid etching process by the glass artist/designer in a work-safe environment?
- Are there any glass-artists/researchers working with this dangerous medium at present?

**Process (standard application) and technical skills**

The Acid Etching process involves the use of an acid that will rapidly corrode glass. This acid is made by heating fluor spar (calcium fluoride) with sulphuric acid and then condensed in water. A Swedish chemist first chemically identified this compound now known as Hydrofluoric acid in 1771. Only the fumes of the hydrofluoric acid were used when acid etching was first developed. Brunswick black, an acid-resistant paint was painted on the surface of plate glass in a decorative design. The glass was then exposed to the highly toxic fumes of the acid that quickly frosted the unprotected untainted areas. When the acid resist was removed it revealed a clear pattern on a frosted background. Clear etching superseded the use of hydrochloric acid fumes after a while. The technique of clear etching required the glass to be painted in the same way but a wall of tallow ( a form of animal fat) was placed around the edge of the glass, like the rim of a tray, then the surface could be flooded with liquid acid. After about one hour, the acid was poured off, leaving the surface etched to a depth of about 0.5 mm. Although clear, this finish was not as transparent as the original, and the glass was described as being 'etched' or 'embossed'. It was often silvered or gilded. The use of hydrofluoric acids is a health and environmental hazard because of the gasses it forms. 'White acid' was made by mixing hydrofluoric acid with an alkali, usually carbonate of soda (washing soda). 'White acid' produced a 'frosting acid' that when applied to glass gave it a dense white frosting over its surface. The process known in the trade as "French embossing" or 'triple embossing' is done with a dilute hydrofluoric acid over the frosting to produce a range of

satin tones. These techniques were frequently used in combination with brilliant cutting (Bender 1997).

Nancy D. Stephenson's paper described the unique process used in the manufacture of the decorative glass-ceramic products. A break-down of the raw components was listed. Her paper described how the raw materials are melted then rolled into sheet form, ready for further manipulation. The blank sheets of photosensitive glass in sheet form are produced in 1.44 mm, 2.03mm and 2.6.7 mm thicknesses. Stephenson (1986) describes these blank sheets as creating the ultimate form. A four step process consisting of exposure, development, acid etching and ceramic firing enables the chosen design to be permanently captured within the body of this special material known and registered as OPELLE. Nancy Stephenson's four step decorative acid etching process of the material registered as Opelle is as follows:

First, the art work is created in black-and-white format, larger than the scale for the final product. Then the original line-art is then photographically reduced to the correct size. The negative of this image is stepped out in multiple on glass-plate tooling of equal size to the photosensitive glass blank, on an opaque emulsion. The glass plate negative and the photosensitive glass sheet are together exposed to collimated ultraviolet light, causing a latent image from the negative to be reproduced in the glass sheet. During the exposure, the glass plate negative is placed against the lithium-silicate glass. Traces of silver and cerium in the glass react to ultraviolet light and make this glass photosensitive. The exact design chosen has now been transferred to the photosensitive glass and is present throughout the sheet's cross section. To make the latent image visible, the development step uses a time and temperature combination to promote a purplish, crystalline growth which later makes possible varied colour and texture within the final product. The balance of time and temperature determine the ultimate glass composition, glass-to-ceramic. The third step of the process is accomplished by etching. During etching, the developed glass sheet is bathed in a solution of dilute hydrofluoric acid. Areas where crystals have formed are many times more soluble in acid

than the surrounding glass and as a result, a pierced or lacy effect is accomplished by selective etching. Depth-etch, a process by which a relief design is etched only partially through the glass, can be achieved within the same part. To achieve this result, a second glass plate negative must be made and the same photosensitive glass sheet is then subsequently exposed in those design areas selected for this treatment. After the development stage, where crystals become visible, the areas selected for relief etching appear lighter and are of lower density crystallization.

During etching, the glass in the developed areas dissolves away, leaving behind the perfect structure of the original design. High density crystals etch more rapidly than low density crystals, creating a varied perfect texture. Once etched, the individual design units separate from the original glass housing and are sent back to the annealing kiln for a final heat treatment. At this stage, the material is transformed into a glass-ceramic and takes on its characteristic texture and opacity. Glass ceramic products exposed to the highest temperature of approximately 800 degrees Celsius for many hours are inherently stronger and more durable than their glass counterparts.

Varieties of hue can be achieved by controlling the ultraviolet exposure rates and development cycles. Shade of white-to-ivory to dark brown can be created. Colour is developed naturally through physical changes in the base glass. No secondary treatments are applied and as a result one can view this design from either side.

Because environmental and health reasons were of some concern, this Case Study was not pursued.

## References

Bender, R.C. 1997. *Brilliant Glass: Brilliant Cut and Acid Etched Glass Decoration*. Swansea, Wales, UK: The Building Conservation Directory 1998.

The Gale Group 2004. Techniques Developed For Characterization Of Photosensitive Glass – Brief Article. *Journal of Research of the National Institute of Standards and Technology, Maryland, USA*. [http://www.findarticles.com/p/articles/mi\\_.01Kz/is\\_6\\_105/ai\\_7720437/print](http://www.findarticles.com/p/articles/mi_.01Kz/is_6_105/ai_7720437/print). (accessed April 3, 2005).

Stephenson, Nancy D. 1986. Photosensitive Glass – Ceramics - A new Generation in Decoration. Corning Glass Works, Corning. NY14831: Wiley Interscience, Materials & Equipment/Whitewares: *Ceramic engineering and Science Proceedings*, (7): 11/12.

## **Appendix C1 (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Six and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Case Study One: Pulling and drawing out (hot glass)**

##### **Sub-category: Stringers**

##### **Technical process**

Photosensitive glass stringers were pulled from a crucible of molten glass using the miniature furnace as the primary heat source. Under safe red photographic light, the photosensitive glass rods were cut into medallions of approximately 20 mm thick, then heated up to 657 degrees Celsius in an electric kiln. At this temperature photosensitive glass softens and can be picked up on a punty (pontil). The punty holding the photosensitive glass medallion was heated in the glory hole until small pinkish-red thread-like objects appeared in the glass. After this '*flaming*' stage the medallion was marvered on a stainless steel plate into a bubble before gathering an outer casing of clear soda lime glass from the crucible inside the furnace. The bulb of hot encased photosensitive glass was then pulled into thin stringers before being put away in a dark box or tube that excluded all light. When cool, the canes or stringers were then cut up into approximately 10 millimetre lengths then made up into ten groups for a systematic experiment involving ultra-violet light exposures for designated lengths of time and heat development at selected temperatures and times in an electric kiln. Heat development firing schedules used for each group can be viewed on the pages following the illustrated experimental results.

## **Equipment**

A testing run of the equipment that was set up in the darkroom was made before the first experiment. The room was darkened and a red photographic safe light was switched on. The ultraviolet light box was placed over the potters' wheel-head; the ultraviolet light was switched on at the same time as the rotating potters' wheel. A test for shuddering of the light box over the wheel while it was operating was made. A digital timer was used to control the length of exposure time for the ultra violet light. Photographs were taken of the light box and all the details were written in the working note book for future reference.

## **Method: Exposing the groups of stringers under UV light**

A method of exposure under ultraviolet light for the photosensitive glass stringers was selected. Exposure times of ten, twenty, thirty, forty and fifty minutes were selected for each group. Each group of was then exposed to ultraviolet light on a rotating turntable.

## **Experimental process**

Each group of stringers was marked off with five pieces of light-blocking tape so as to give a range of ultraviolet light exposure from ten minutes to fifty minutes. Each group of stringers was then taped down with clear tape onto the potter's wheel head in a horizontal position. Two groups of stringers were kept as control groups, and were not exposed to the ultra violet light but were heat developed. The count-up timer was set for ten minutes, the ultraviolet light was switched on and the wheel-head under the light-box was switched on and rotated for the full count of the timer. The ultra violet light was switched off then the ten minute light blocking tape at the top of each group of stringers was removed, this ten minute subtractive tape removal procedure was continued until all the light-blocking tape on each group of stringers was removed. The last piece of taped photosensitive glass area was marked with a pen so as to indicate that this blocked off area received only ten minutes exposure from the

ultraviolet light. The four groups were placed into four separate light proof containers ready for individual heat development at 495 degrees, 505 degrees, 525 degrees and 550 degrees Celsius for 90 minutes. The remaining four groups were placed into another four light proof containers for heat development at 495 degrees, 505 degrees, 525 degrees and 550 degrees Celsius for 120 minutes. The two control groups were developed, group 1 at 495 degrees Celsius for 90 minutes and group 2 at 525 degrees Celsius for 120 minutes

**Warning.** Damage to the human eye can occur if it is exposed to ultraviolet light without wearing the recommended protective eye glasses.

It is advisable that the UV light is switched off when opening the UV box after the exposure stage.

### **Heat and Colour development**

Colour development was achieved by timed exposure under ultra-violet light, followed by heating the ultraviolet light exposed photosensitive glass stringers in an electric kiln at a defined temperature for a certain length of time.

A range of five heat development temperatures were chosen for ninety minutes and one hundred and twenty minutes. The heat development temperature range was at 495, 505, 525 and 550 degrees Celsius.

Figure 1(a).

**Case Study One: sub-category 1: Stringers**

**Experiment:** Firing schedule for photosensitive glass stringers exposed to UV light then heat developed for 90 minutes in an electric kiln controlled by a digital controller.

Cycle	↑ ↓ Temp	Temp °C	@ Time	RATE/Temp/Time
1.	↑	495		150
2.	→	495	F	90
3.	↓	460		80
4.	→	460	F	60
5.	↓	400		60
6.	→	300	F	30
7.	↓	90		30
8.	-	000	F	000

**Control Group 1.**  
Ultraviolet light exposure: Nil.  
Heat development: @ 495 degrees Celsius for 90 minutes.

Cycle	↑ ↓ Temp	Temp °C	@ Time	RATE/Temp/Time
1.	↑	495		150
2.	→	495	F	90
3.	↓	460		80
4.	→	460	F	60
5.	↓	400		60
6.	→	300	F	30
7.	↓	90		30
8.	-	000	F	000

**Group: 1.1.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 495 degrees Celsius for 90 minutes.

Cycle	↑ ↓ Temp	Temp °C	@ Time	RATE/Temp/Time
1.	↑	505	F	150 min
2.	→	505	F	90
3.	↓	470		80
4.	→	470	F	60
5.	↓	400		60
6.	→	300	F	30
7.	↓	90		30
8.	-	000	F	000

**Group: 1.2.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 505 degrees Celsius for 90 minutes.

Cycle	↑ ↓ Temp	Temp °C	@ Time	RATE/Temp/Time
1.	↑	525	F	150 min
2.	→	525	F	90
3.	↓	520		80
4.	→	520	F	60
5.	↓	400		60
6.	→	300	F	30
7.	↓	90		30
8.	-	000	F	000

**Group: 1.3.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 525 degrees Celsius for 90 minutes.

Cycle	↑ ↓ Temp	Temp °C	@ Time	RATE/Temp/Time
1.	↑	550	F	150
2.	→	550	F	90
3.	↓	520		80
4.	→	520	F	60
5.	↓	400		60
6.	→	300	F	30
7.	↓	90		30
8.	-	000	F	000

**Group: 1.4.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 550 degrees Celsius for 90 minutes.

Figure 1(b).

**Case study One: sub-category 1: Stringers.**

**Experiment:** Firing schedule for photosensitive glass stringers exposed to UV light then heat developed for 120 minutes in an electric kiln controlled by a digital controller.

Cycle	↑ ↓	TEMP °C	Ⓢ	RATE/TIME
1.	↑	525	Ⓢ	150
2.	→	525	Ⓢ	120
3.	↓	520	Ⓢ	60
4.	→	520	Ⓢ	60
5.	↓	400	Ⓢ	60
6.	→	300	Ⓢ	30
7.	↓	90	Ⓢ	30
8.	-	000	0	000

**Control Group 2.**  
Ultraviolet light exposure: Nil.  
Heat development: @ 495 degrees Celsius for 120 minutes.

Cycle	↑ ↓	TEMP °C	Ⓢ	RATE/TIME
1.	↑	495	Ⓢ	150
2.	→	495	Ⓢ	70
3.	↓	460	Ⓢ	60
4.	→	460	Ⓢ	60
5.	↓	400	Ⓢ	60
6.	→	300	Ⓢ	30
7.	↓	90	Ⓢ	30
8.	-	000	0	000

**Group: 2.1.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 495 degrees Celsius for 120 minutes.

Cycle	↑ ↓	TEMP °C	Ⓢ	RATE/TIME
1.	↑	505	Ⓢ	150
2.	→	505	Ⓢ	120
3.	↓	470	Ⓢ	60
4.	→	470	Ⓢ	60
5.	↓	400	Ⓢ	60
6.	→	300	Ⓢ	30
7.	↓	90	Ⓢ	30
8.	-	000	0	000

**Group: 2.2.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 505 degrees Celsius for 120 minutes.

Cycle	↑ ↓	TEMP °C	Ⓢ	RATE/TIME
1.	↑	525	Ⓢ	150
2.	→	525	Ⓢ	120
3.	↓	520	Ⓢ	60
4.	→	520	Ⓢ	60
5.	↓	400	Ⓢ	60
6.	→	300	Ⓢ	30
7.	↓	90	Ⓢ	30
8.	-	000	0	000

**Group: 2.3.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 525 degrees Celsius for 120 minutes.

Cycle	↑ ↓	TEMP °C	Ⓢ	RATE/TIME
1.	↑	550	Ⓢ	150
2.	→	550	Ⓢ	120
3.	↓	520	Ⓢ	60
4.	→	520	Ⓢ	60
5.	↓	400	Ⓢ	60
6.	→	300	Ⓢ	30
7.	↓	90	Ⓢ	30
8.	-	000	0	000

**Group: 2.4.**  
Ultraviolet light exposure: 10, 20, 30, 40, 50 minutes.  
Heat development: @ 550 degrees Celsius for 120 minutes.



## **Appendix Ci (b)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Six and contains the processes and technical details of the following scoping case study sub-category experiments:

#### **Case Study One: Pulling and drawing out (hot glass)**

##### **Sub-category : Murrine**

##### **Technical process**

An outer casing of coloured glass, from the miniature furnace crucible containing the molten coloured glass, was gathered on a punty that held a disc of '*flamed*' photosensitive glass. The canes were cut up by hand into short oblong pieces (murrine) then sorted into twelve groups for a systematic experiment involving ultra-violet light exposures for designated lengths of time and heat development in an electric kiln for heat development at selected temperatures and times. Thirty-six experiments of murrine were set up. Heat development firing schedules used for each group of three experiments can be viewed at the base of the page illustrating the experimental results.

##### **Equipment**

A trial run of the equipment was set up in the darkroom before the first experiment was commenced.

##### **Method:**

Exposing the photosensitive murrine groups under ultra violet light.

A method of exposure under ultraviolet light for the photosensitive glass murrine was selected. Three exposure times of ten minutes, twenty minutes and

thirty minutes were selected for each group. Each group of murrine was then exposed to ultra-violet light on a rotating turntable.

### **Experimental process**

Place all photosensitive glass murrine into childrens' play-dough so that they standup vertically. Set the count-up timer for ten minutes and switch on the ultraviolet light .Rotate the wheel head under the light box until the timer rings. Switch off the ultraviolet light then remove the ten minute group of murrine. Keep this ten minute group in a light proof container for later heat development. Continue the procedure for another ten minutes. Remove the twenty minute murrine group and continue exposing the remainder of the murrine for ten more minutes then place this last group of exposed murrine in the thirty minute group of exposed murrine in a light proof container. Finally, wrap the light proof containers in a black photographic sleeve and place in a secure dark box until ready for heat development. Using Play-dough is preferable to using clay because clay clings to glass when heated in a kiln and Play Do burns away.

**Warning.** The author points out that damage to the human eye can occur if it is exposed to ultraviolet light without wearing the recommended protective eye glasses.

### **Planning the construction/design of firing schedules**

A series of kiln firing programs using Graham Stone's Firing Schedules for Glass: The Kiln Companion 2000, were designed for the heat development phase for each group of murrine. A pilot experiment to refine procedure was conducted.

### **Heat and Colour development**

Colour development was achieved by timed exposure under ultra-violet light, in a light box followed by heating the exposed photosensitive glass murrine in an electric kiln at a defined temperature for a certain length of time. Six heat development temperatures were chosen for ninety minutes and another six at one hundred and twenty minutes. The heat development temperature range was 490, 495, 505, 525, 550 and 575 degrees Celsius.

### **References**

Stone, Graham 1999-2000. *Firing Schedules for Glass: The Kiln Companion 2000*. 20 Sydenham St, Highett Victoria 3190, Australia.

## **Appendix Ciii (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Six and contains the processes and technical details of the following successful case study sub-category experiments:

#### **Case Study Three: Bead-making/Flame-working (hot glass)**

##### **Sub-category: Bead-making**

A series of bead making experiments, using Spectrum #96 White Opalescent canes and medium to large chips of Photosensitive glass a propane gas and oxygen 'Hot-head' bead making bench torch was used. A distinctive shape was assigned to each bead based on its ultraviolet light exposure time. Having a definite shape that was recognizable by touch was important as it was often difficult to distinguish one bead from another under safe red photographic light. The beads were shaped using a combination of heat, gravity and tools such as graphite paddles, mashers, tweezers and picks. The twelve different shapes ranged from ten minutes to ninety minutes of ultraviolet light exposure. The distinctive shape of each bead also made recognition easier after heat development.

A control set of beads was made, shaped and heat developed for 181 minutes at a temperature of 600 degrees Celsius without exposing the beads to ultraviolet light. Seven sets of photosensitive beads with ultraviolet light exposure times starting from ten minutes and ending at ninety minutes were made. Seven heat development temperatures were selected for the time of one hundred and eighty one minutes.

Heat development firing schedules used for each group can be viewed on the pages following the illustrated experimental results. Data comparing the exposure times of the twelve differently shaped beads across the seven heats Development temperatures for one hundred and eighty one minutes can be seen.

### **Equipment**

A test run of the equipment that was set up in the darkroom was made before the first bead timed ultraviolet light exposure experiment. The room was darkened and a red photographic 'safe light' was switched on. The ultraviolet light box was placed over the potters' wheel-head. A small bucket of wet sand was placed on the wheel-head for holding the beads on their mandrels. The ultraviolet light was switched on at the same time as the rotating potters' wheel. A test for shuddering of the light box over the wheel while it was operating was made. A digital timer was used to control the length of exposure time for the ultra violet light. Photographs were taken of the light box and all the details were written in the working note book for future reference.

**Warning.** Damage to the human eye can occur if it is exposed to ultraviolet light without wearing the recommended protective eye glasses.

It is advisable that the UV light is switched off when opening the UV box after the exposure stage.

### **Planning the construction/design of firing schedules**

A series of kiln firing programs using Graham Stone's Firing Schedules for Glass: The Kiln Companion 2000 was designed for the heat development phase for each group of beads. A pilot experiment to refine procedure was conducted.

### **Heat and Colour development**

Colour development was achieved by timed exposure of the twelve beads under ultra-violet light, followed by heating the photosensitive glass beads in an electric kiln at a defined temperature for a certain length of time. A range of seven heat development temperatures were chosen for one hundred and eighty one (181) minutes.

### **Technical processes**

#### **Experimental process: Exposing the photosensitive bead groups under ultra violet light**

A method of exposure under ultraviolet light for the photosensitive glass beads was selected. Exposure times of ten, twenty, thirty, forty and minutes were selected for each group. Each group of was then exposed to ultra-violet light on a rotating turntable.

Each bead in its group was marked off with pieces of light-blocking tape so as to give a range of ultraviolet light exposure from ten minutes to ninety minutes. Each group of beads was then placed in a container of damp sand that was securely held down on top wheel-head of the potters' wheel. One group of beads was kept as a control group, and was not exposed in the ultra violet light but was heat developed. The count-up timer was set for ten minutes, the ultraviolet light was switched on and the wheel-head under the light-box was switched on and rotated for the full count of the timer. The ultra violet light was switched off then the ten minute light blocking tape at the top of the beads exposed for ten minutes was removed. This ten minute subtractive tape removal procedure was continued until all the light-blocking tape on each bead was removed. The eight groups were placed into eight separate light proof containers ready for individual heat development at 495 degrees, 505 degrees, 525 degree, 550, 575, 600, and 625 degrees Celsius for 181 minutes. The control group was developed at 600 degrees Celsius for 181 minutes.

### **References**

Stone, Graham 1999-2000. *Firing Schedules for Glass: The Kiln Companion*  
2000. 20 Sydenham Street, Highett, Victoria, 3190, Australia.

## **Appendix Cvi (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Six and contains the processes and technical details of the following successful case study sub-category experiments:

#### **Case Study Six: Free blowing**

##### **Sub-category: Crowns, Bullions (disks)**

#### **Technical process**

##### **Designing the experiment**

First of all, it was necessary for me to find out how to mathematically calculate the amount of photosensitive glass needed to make a disk (bullion or crowns) of a certain size (diameter) from a rod of photosensitive glass. The first step was to measure the diameter of the rod of photosensitive glass. The second step was to decide on the diameter of the blown disk. Selecting the thickness of photosensitive glass in the disk was the third step. In a personal communication from Dr. Eric F. May (2006) N.I.S.T. Maryland, Washington DC, USA, the method of calculating the amount of photosensitive glass was given to me as follows:

In measuring the diameter of the photosensitive glass rod and estimating the diameter of the proposed glass disk. The volume of a cylindrical rod is

$$V_{rod} = \pi d^2 L / 4$$

where the diameter and length of the rod are  $d$  and  $L$ , respectively. The volume of the thin disk is

$$V_{disk} = \pi D^2 t / 4$$

where the diameter and thickness of the disk are  $D$  and  $t$ , respectively. The fraction of glass originally in a rod that is retained once it is converted to a disk is  $k$ ; for example if 5 % of the glass is lost then  $k = 0.95$ .

To work out the rod dimensions required to produce a disk of given diameter and thickness:

$$V_{disk} = k V_{rod}$$

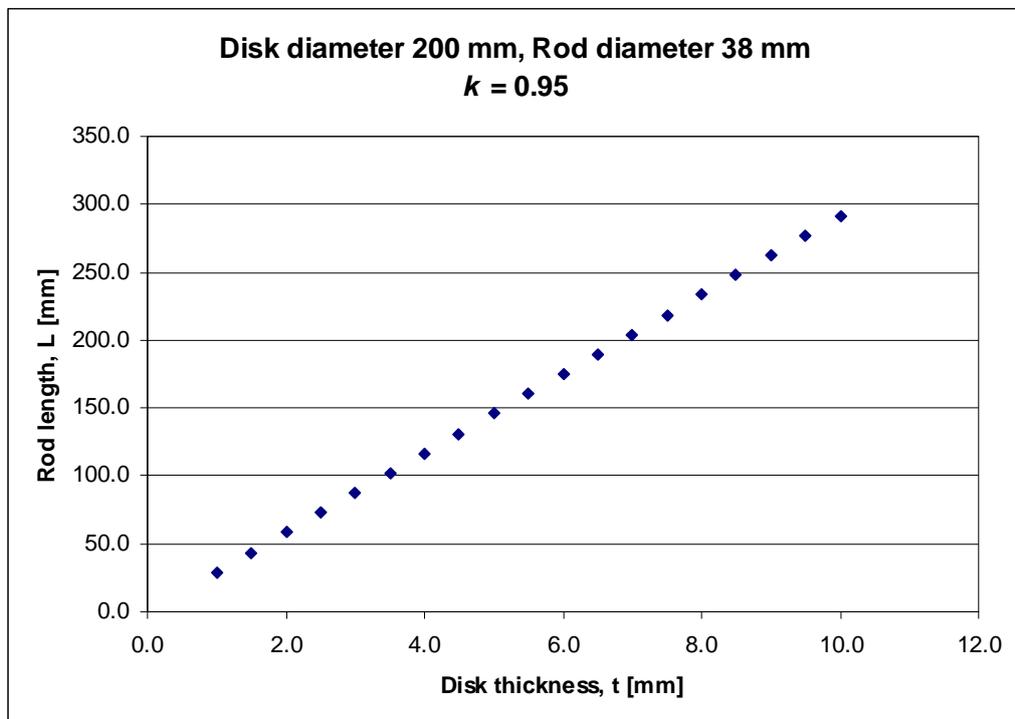
$$\pi D^2 t / 4 = k \pi d^2 L / 4$$

To calculate the length of a rod with given diameter required to create a disk of specified thickness and diameter, the formula is

$$L = (t/k)(D/d)^2$$

Below is an example for a disk diameter of 200 mm, a rod diameter of 38 mm and  $k = 0.95$ .

Rod diameter d [mm]	Disk diameter D [mm]	Disk volume as a fraction of rod's volume k
38.0	200.0	0.95
Disk thickness t [mm]	Rod Length L [mm]	
1.0	29.2	
1.5	43.7	
2.0	58.3	
2.5	72.9	
3.0	87.5	
3.5	102.1	
4.0	116.6	
4.5	131.2	
5.0	145.8	
5.5	160.4	
6.0	175.0	
6.5	189.5	
7.0	204.1	
7.5	218.7	
8.0	233.3	
8.5	247.8	
9.0	262.4	
9.5	277.0	
10.0	291.6	

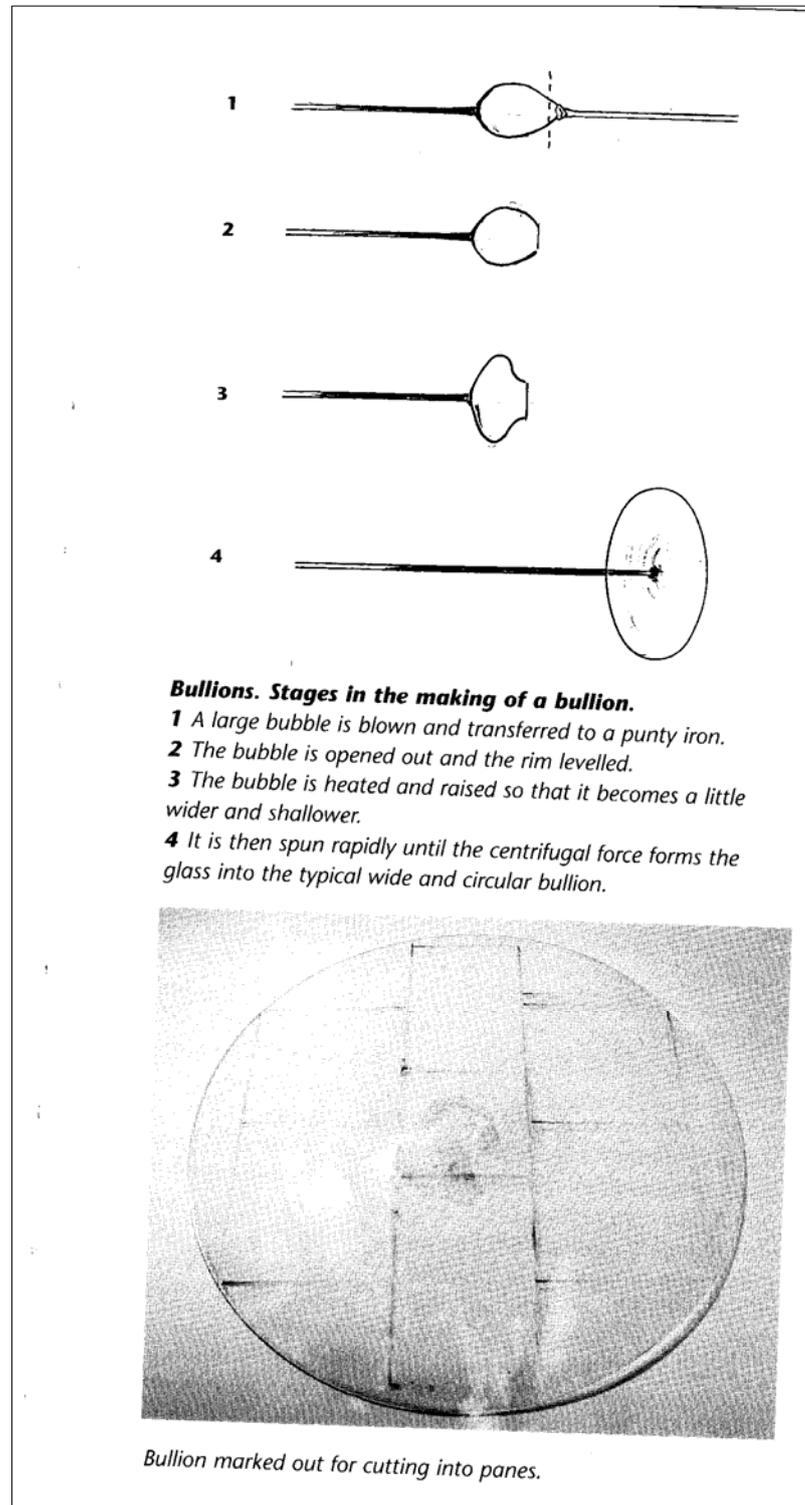


Once the three steps had been taken, their measurements were used for calculating of how much of the photosensitive glass rod would be needed for a blown disk (bullion or crown) at a certain thickness.

The fourth step taken was to print out the mathematical calculation spreadsheet and calculate three degrees of thickness for glass variations for the experiment. The fifth step was to take the photosensitive glass rod and mathematical calculation spreadsheet to David Hay who would expertly chip off the required medallion of photosensitive glass for each disk that need to be blown.

**Figure 110.**

Stages and process in making a Crown, Bullion (disk).



## **Equipment**

A Ricoh Caplio RR1 digital camera was used to photograph the results in situ and transparency slides were photographed with an Ashai Pentax spotmatic F camera. I was not satisfied with the printouts of these results so I decided to use my UMAX PowerLook II Binuscan Photoperfect scanner to reproduce the glassy quality of the disks by directly scanning them through the above scanner. This scanner can scan reflective art up to 8.5 x 11 inches (21 x 28 cms).

## **Method of exposure to ultraviolet light**

The cut up '*pie slices*' of the masking material were applied to the glass disk (bullion or crown) which was then placed onto the potters' wheel head. It was secured to the wheel-head by using 'blue tac' adhesive. The first '*pie slice*' was then removed before lowering the ultraviolet light box onto the potter's wheel frame. The count-up timer was set and the ultraviolet light was switched on. The potters' wheel head under the box was rotated, with the timer set to ring at five minute intervals. The ultraviolet light was switched off after five minutes, the box lid opened then the next '*pie slice*' marking strip was removed. This procedure was followed until all the '*pie slices*' had been removed. Once this has been completed, the exposed disk was removed from the wheel head. The disk was marked with letter or number in the centre for identification then wrapped in a black photographic sleeve and placed in a secure dark box until ready for the heat development stage.

## **Experimental process**

### **Testing the hypothesis by action**

The timed '*pie-slice*' subtractive method was selected because of the shape of the disk (bullion or crown) The decision for the amount of time allocated per '*pie slice*' was five minutes and number of '*pie slices*' to be exposed was ninety per disk The masking material chosen for each '*pie slice*' was a black kitchen drawer lining plastic with an adhesive backing. The masking material

was measured to fit each individual disk as some were slightly larger than others. These measurements were made and the '*pie slices*' cut out in the darkroom under safe red photographic light.

### **Bullion/Crown (disk) experiments**

The eight blown photosensitive glass disk experiments were divided into two groups. The following timed heat development experiments were made on the eight blown photosensitive glass disks. The temperature range was from 525 to 600 degrees Celsius and the length or rate of time taken to hold the experiment at a particular temperature was 271 minutes (4hrs 30 minutes).

### **Control Disks**

Disk 1-Heat development temperature 525 degrees Celsius for 271 minutes  
Disk 2-Heat development temperature 550 degrees Celsius for 271 minutes.  
Disk 3-Heat development temperature 575 degrees Celsius for 271 minutes.  
Disk 4-Heat development temperature 600 degrees Celsius for 271 minutes.

### **'Variable' (d) Disks**

Disk A - Heat development temperature 525 degrees Celsius for 271 minutes.  
Disk B - Heat development temperature 550 degrees Celsius for 271 minutes.  
Disk C – Heat development temperature 575 degrees Celsius for 271 minutes.  
Disk D – Heat development temperature 600 degrees Celsius for 271 minutes.

### **Colour development.**

Colour development was achieved by timed exposure under ultra-violet light, followed by heating the exposed photosensitive glass disk (bullion or crown) in an electric kiln at a defined temperature for a certain length of time.

**Heat development**

A range of four heat development temperatures was selected for the Control and the Variable (d) disks (bullion or crowns). The thickness of the photosensitive glass in the eight disks was 5mm in the centre to 1 mm at the edges.



## **Appendix Cvii (a)**

### **Aesthetic, Creative and Innovative uses for Photosensitive glass in Art-glass Production: Case Studies in Studio practice**

This appendix supplements Chapter Six and contains the data presentation issues, the presentation analysis and the illustrated colour coded comparative timed ultraviolet exposures results tables and comparative heat development tables. [The set of colour coded comparative heat development tables from figure 82a, to figure 97b can be viewed as a supplement to Case Study Four.](#)

**Case Study Four:** Kiln casting/Kiln formed glass (Warm glass)

**Sub-category:5.4.2:** [Simple open face kiln formed Pate de Verre Triaxial blends.](#)

#### **Data presentation issues**

The issue of presenting the data was to present them as they looked to the naked eye when scanned into the computer and printed out in table form. These original triaxials were scanned and were presented in alphabetically numbered sections of a group. For example Figure 88.

This type of presentation did not indicate what colours had developed in the disks so the data was then additionally presented in the form of comparative colour coded linear tables with coloured squares alongside each numbered disk. For example Figure 88a (triaxial No.22). These coded colours were observed by enlarging each disk so that the hidden developed colours could be seen.

Ultra-violet light exposure times, heat development times and the selected temperature ranges were recorded.

#### **Presentation analysis**

**1. Comparative timed ultraviolet exposure results tables as illustrated in all figures with a d appendage** were drawn up showing ultra violet light exposure

times of 5, 10, 20 and 30 minutes. The numbered disk results of all the triaxial experiments were placed into the four numbered circular spaces that corresponded with the ultra violet light exposures. The temperature of the ultraviolet light exposure experiments was placed in a heat development column that showed the temperature that each triaxial was heat developed at. Below the temperature entry, the length of time it took to develop the particular triaxial was recorded.

**2. The coded comparative colour/time results tables as illustrated in all figures with f** appendages complemented the comparative timed ultraviolet exposure results table discussed above and indicated the numbers of the triaxial at the top of the columns. The time that the triaxial underwent ultraviolet light exposure, the temperature and time that the triaxial was heat developed for and the colours seen in the disks were illustrated as coloured squares and printed out in columns that corresponded with the circular columns containing the images of the disks in the comparative timed ultraviolet exposure results.

**A set of comparative heat development results tables** was drawn up. These tables showed five columns for circular spaces for entry of the temperatures of 490, 495, 505, 525, and 550 degrees Celsius. The numbered disk results of all the triaxial experiments for the above temperatures were placed between the ultraviolet light exposure time column (above) and the heat development time column (.below). The heat development times ranged from 90, 120, 180 and 240 minutes.

**A set of colour coded comparative heat development tables** was then drawn up to correspond with the five circular spaces discussed above. Each table showed a triaxial number at the beneath each temperature column. Below the triaxial number in the heat development temperature column, opposite one of the fifteen disk numbers, a number of coloured squares indicate the colours I saw in the disk. The time each triaxial took at the heat development stage is entered below the timed ultraviolet light exposure column.

The comparative heat development results tables and the corresponding colour coded comparative heat development tables were printed on the same page for comparison. By referring to the comparative heat development tables and the corresponding colour coded comparative heat development tables that indicate a common ultraviolet light exposure, a balance of the colours needed or wanted can be selected. These tables start from Figure 82a and end with 93b.

**Figure 82a:** Comparative heat development results table.

Case Study Four:Kiln Formed Photosensitive glass		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category 2:</b> <i>Pate de Verre</i> <i>Triaxials</i> <i>Comparative Heat</i> <i>Results</i>		5	1.					
			2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 82b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No: 48	495 deg. Celsius No: 48	505 deg. Celsius No: 33	525 deg. Celsius No: 21	550 deg. Celsius No: 7
<b>Sub-category 2:</b> <i>Pate de Verre-Triaxials</i> <i>Comparative colour</i> <i>results</i>		5	1.					
			2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 83a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category 2:</b> <i>Pate de Verre Trioxials</i> <b>Comparative Heat Results</b>		10	1.					
			2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 83b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No.	495 deg. Celsius No. 47	505 deg. Celsius No. 32	525 deg. Celsius No. 20	550 deg. Celsius No. 6
<b>Sub-category 2:</b> <i>Pate de Verre Trioxials</i> <b>Comparative colour results</b>		10	1.					
			2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 84a: Comparative heat development results table.**

Case Study Four: Kiln Formed Photosensitive glass		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category 2:</b> Pate de Verre Triaxials Comparative Heat Results  KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		Heat develop- ment in mins						
		20	1.					
		180	2.					
		3.						
		4.						
		5.						
		6.						
		7.						
		8.						
		9.						
		10.						
		11.						
		12.						
		13.						
		14.						
		15.						

**Figure 84b: Comparative colour coded/heat development results table.**

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No: 46	495 deg. Celsius No: 31	505 deg. Celsius No: 19	525 deg. Celsius No: 5
<b>Sub-category 2:</b> Pate de Verre-Triaxials Comparative colour results  KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		Heat develop- ment in mins					
		20	1.				
		180	2.				
		3.					
		4.					
		5.					
		6.					
		7.					
		8.					
		9.					
		10.					
		11.					
		12.					
		13.					
		14.					
		15.					

**Figure 85a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
Sub-category 2: Pate de Verre Triaxials Comparative Heat Results		30	1.					
			2.					
KEY		Heat develop- ment in mins.	3.					
			4.					
1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Soda-Lime 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		180	5.					
		6.						
		7.						
		8.						
		9.						
		10.						
		11.						
		12.						
		13.						
		14.						
		15.						
		16.						
		17.						
		18.						
		19.						
		20.						
		21.						

**Figure 85b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No:	495 deg. Celsius No: 45	505 deg. Celsius No: 30	525 deg. Celsius No: 18	550 deg. Celsius No: 4
Sub-category 2: Pate de Verre-Triaxials Comparative colour results		30	1.					
			2.					
KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Soda-Lime 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		180	3.					
		4.						
		5.						
		6.						
		7.						
		8.						
		9.						
		10.						
		11.						
		12.						
		13.						
		14.						
		15.						

**Figure 86a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category 2:</b> <i>Pate de Verre Triaxials</i> <i>Comparative Heat Results</i>	<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	30	1.					
		120	2.					
		3.						
		4.						
		5.						
		6.						
		7.						
		8.						
		9.						
		10.						
		11.						
		12.						
		13.						
		14.						
		15.						

**Figure 86b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No: 56	495 deg. Celsius No: 49	505 deg. Celsius No: 34	525 deg. Celsius No: 22	550 deg. Celsius No: 8
<b>Sub-category 2:</b> <i>Pate de Verre-Triaxials</i> <i>Comparative colour results</i>	<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	30	1.					
		120	2.					
		3.						
		4.						
		5.						
		6.						
		7.						
		8.						
		9.						
		10.						
		11.						
		12.						
		13.						
		14.						
		15.						

**Figure 87a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		UV exposure for mins.	No.	490 deg Celsius	495 deg Celsius	505 deg Celsius	525 deg. Celsius	550 deg. Celsius	
<b>Sub-category 2:</b> <i>Pate de Verre-Triaxials</i> <b>Comparative Heat Results</b>  <b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		Heat develop- ment in mins							
		20	1.						
		120	2.						
			3.						
			4.						
			5.						
			6.						
			7.						
			8.						
			9.						
			10.						
			11.						
			12.						
			13.						
			14.						
	15.								

**Figure 87b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No. 57	495 deg. Celsius No. 50	505 deg. Celsius No. 35	525 deg. Celsius No. 23	550 deg. Celsius No. 9
<b>Sub-category 2:</b> <i>Pate de Verre-Triaxials</i> <b>Comparative colour results</b>  <b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		Heat develop- ment in mins						
		20	1.					
		120	2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
	15.							

**Figure 88a:** Comparative heat development results table.

Case Study Four: Kiln formed Photosensitive glass		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius	
Sub-category 2: <i>Pate de Verre Triaxials</i> Comparative Heat Results	KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	5	Heat devel- opment in mins.  120	1.					
				2.					
				3.					
				4.					
				5.					
				6.					
				7.					
				8.					
				9.					
				10.					
				11.					
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				13.					
				14.					
				15.					

**Figure 88b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No.	495 deg. Celsius No.	505 deg. Celsius No. 37	525 deg. Celsius No. 25	550 deg. Celsius No. 11		
Sub-category: 2. <i>Pate de Verre-Triaxials</i> Comparative colour results	KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	5	Heat devel- opment in mins.  120	1.						
				2.						
				3.						
				4.						
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				6.						
				7.						
				8.						
				9.						
				10.						
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				13.						
				14.						
				15.						

**Figure 89a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		DIV expo- sure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category 2:</b> <i>Pate de Lere-Triaxials</i> <b>Comparative Heat Results</b>		30	1.					
			2.					
			3.					
			4.					
			5.					
		90	6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 89b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		DIV expo- sure for mins.	No.	490 deg. Celsius No:59	495 deg. Celsius	505 deg. Celsius No:38	525 deg. Celsius No:26	550 deg. Celsius No:12
<b>Sub-category 2:</b> <i>Pate de Lere-Triaxials</i> <b>Comparative colour results</b>		30	1.					
			2.					
			3.					
			4.					
			5.					
		90	6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 90a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		UV exposure for mins	No.	400 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
Sub-category 2: <i>Pate de Verre-Triaxials</i> Comparative Heat Results.		20	1.					
			2.					
KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		90	3.					
			4.					
			5.					
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			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 90b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins	No.	400 deg. Celsius No: 60	495 deg. Celsius No:	505 deg. Celsius No: 39	525 deg. Celsius No: 27	550 deg. Celsius No: 13
Sub-category 2: <i>Pate de Verre-Triaxials</i> Comparative colour results		20	1.					
			2.					
KEY 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White		90	3.					
			4.					
			5.					
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			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 91a:** Comparative heat development results table.

Case Study Four: Kiln Formed Photosensitive glass		UV exposure m ins.	No.	490 deg Celsius	495 deg Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category 2:</b> <i>Pate de Verre Triaxials</i> Comparative Heat Results.		10	1.					
			2.					
			3.					
			4.					
			5.					
		90	6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 91b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass		UV exposure for mins.	No.	490 deg. Celsius No: 61	495 deg. Celsius No:	505 deg. Celsius No: 40	525 deg. Celsius No: 28	550 deg. Celsius No: 14
<b>Sub-category 2:</b> <i>Pate de Verre-Triaxials</i> Comparative colour/temp results		10	1.					
			2.					
			3.					
			4.					
			5.					
		90	6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					



**Figure 93a:** Comparative heat development results table.

Case Study Four: KilnFormed Photosensitive glass Sub-category: 2 <i>Fuite de Tiers-Triaxials</i> Comparative Heat Results		UV expo- sure for mins.	No:	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 80% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	Heat devel- opment in mins	10	1.					
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		3.						
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		13.						
		14.						
		15.						

**Figure 93b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass Sub-category: 2 <i>Fuite de Tiers-Triaxials</i> Comparative colour results		UV expo- sure for mins.	No:	490 deg. Celsius No: 58	495 deg. Celsius No: 51	505 deg. Celsius No: 36	525 deg. Celsius No: 24	550 deg. Celsius No: 10
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 80% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	Heat devel- opment in mins	10	1.					
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**Figure 95a:** Comparative heat development results table.

<b>Case Study Four:</b> <b>Kiln Formed Photosensitive glass</b> <i>Sub-category: 2</i> <i>Pate de Verre-Triaxials</i> <i>Comparative Heat Results</i>		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	20	1.						
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**Figure 95b:** Comparative colour coded/heat development results table.

<b>Case Study Four:</b> <b>Kiln casting/Kiln formed glass</b> <i>Sub-category: 2</i> <i>Pate de Verre-Triaxials</i> <i>Comparative colour results</i>		UV exposure for mins.	No.	490 deg. Celsius No: 53	495 deg. Celsius No: 43	505 deg. Celsius No:	525 deg. Celsius No:	550 deg. Celsius No:
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	20	1.						
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**Figure 96a:** Comparative heat development results table.

Case Study <b>Four-Kiln Formed Photosensitive glass.</b>		UV exposure for mins.	No.	490 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>Sub-category: 2.</b> <i>Pate de Verre-Triaxials</i> <b>Comparative Heat Results.</b>	<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	10	1.					
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**Figure 96b:** Comparative colour coded/heat development results table.

Case Study Four: <b>Kiln casting/Kiln formed glass</b>		UV exposure for mins.	No.	490 deg. Celsius No: 54	495 deg. Celsius No: 44	505 deg. Celsius No:	525 deg. Celsius No:	550 deg. Celsius No:
<b>Sub-category: 2.</b> <i>Pate de Verre-Triaxials</i> <b>Comparative colour results</b>	<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	10	1.					
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**Figure 97a:** Comparative heat development results table.

Case Study Two: Recycling crushed Photosensitive glass Sub-category: 2. Date de l'ère-Triaxials Comparative Results		UV exposure for mins.	No.	480 deg. Celsius	495 deg. Celsius	505 deg. Celsius	525 deg. Celsius	550 deg. Celsius
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	5							
	Heat development in mins.	240						
			1.					
			2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

**Figure 97b:** Comparative colour coded/heat development results table.

Case Study Four: Kiln casting/Kiln formed glass Sub-category: 2. Date de l'ère-Triaxials Comparative colour results		UV exposure for mins.	No.	490 deg. Celsius No. 55	495 deg. Celsius No.	505 deg. Celsius No.	525 deg. Celsius No.	550 deg. Celsius No.
<b>KEY</b> 1. 100% Photo-Sensitive glass 2. 80% Photo Sens 20% Soda-Lime 3. 80% Photo Sens 20% Opal White 4. 60% Photo Sens 40% Soda-Lime 5. 60% Photo Sens 20% Soda-Lime 20% Opal White 6. 60% Photo Sens 40% Opal White 7. 40% Photo Sens 60% Soda-Lime 8. 40% Photo Sens 40% Soda-Lime 20% Opal White 9. 40% Photo Sens 20% Soda-Lime 40% Opal White 10. 40% Photo Sens 60% Opal White 11. 20% Photo Sens 80% Soda-Lime 12. 20% Photo Sens 40% Soda-Lime 20% Opal White 13. 20% Photo Sens 40% Soda-Lime 40% Opal White 14. 20% Photo Sens 20% Soda-Lime 60% Opal White 15. 20% Photo Sens 80% Opal White 16. 100% Soda-Lime 17. 80% Soda-Lime 20% Opal White 18. 60% Soda-Lime 40% Opal White 19. 40% Soda-Lime 60% Opal White 20. 20% Soda-Lime 80% Opal White 21. 100% Opal White	5							
	Heat development in mins.	240						
			1.					
			2.					
			3.					
			4.					
			5.					
			6.					
			7.					
			8.					
			9.					
			10.					
			11.					
			12.					
			13.					
			14.					
			15.					

### **Criteria for the interpretation of the results**

The criteria for the interpretation of the data results were the ultraviolet exposure times, the heat development times and the heat development temperatures of the triaxial experiments and the variety of colours seen in each enlarged triaxial disk. By using the triaxial blending and the line blending processes, a systematic experimental framework has been achieved that will meet my objective of how much photosensitive glass is needed to develop weak colour, medium colour and strong colour and any other unknown special colour results.

### **Comparative colour coded heat/time developed results**

Tables were designed to illustrate my analytical colour coded results.

Colour coded interpretation of each disk in the triaxials was a way of illustrating what colours had developed according temperature/time.

Each table consists of a single ultraviolet light exposure and heat development time and a numbered ingredient list alongside five columns of heat development temperatures. The coded letters interpreting the colours seen were entered according to number in each column and correspond with the coded colours placed alongside the scanned illustrations of the disks as described in the research procedures heading.

### **Data interpretation and analysis**

The data were analysed by comparing the results of the colour coded colour/time results with the coded colour/heat results and then cross referenced according to the times the data were exposed to ultraviolet light.

Data interpretation was made by reading along the number of the disk in the colour coded comparative ultraviolet light exposure and timed heat development results table. These colour coded comparative ultraviolet light exposure tables showed the results that were obtained by the length of time the triaxial disks were exposed.

These numbered visual ultraviolet light exposure results could then be compared with the disk that corresponded to the same number shown in the comparative time and heat development table and analysed. The colour coded data were then placed

into five or four columns according to their temperature development rates and could be compared.

**Re: Written permission to use your illustrations for 'Volcano Dream' and Generation 3 Bead-maker' furnaces.**

Dudley Giberson [joppaglass@mcttelecom.com]

Sent: Friday, 3 December 2010 9:53 PM

To: Heather May

Dear Heather,

I printed a letter and signed it, scanned it and return it here as a jpg attachment. Hope this fills the bill.

Sincerely,

Dudley

PS. Please send me a copy of your thesis when you are done. Dec. 14 is my birthday.

**Joppa Glassworks, Inc.**

Dudley F. Giberson, Jr., President

P.O. Box 202

Warner, N.H. 03278

ph 603-456-3569; Fax 603-456-2138

e-mail <joppaglass@conknet.com>

To Whom It May Concern:

I hereby give permission for Heather May to include "Volcano Dream" and "Generation 3 Bead-maker" furr higher degree thesis for the Curtin University of Tech communicate this material via the Australasian Digital permission is granted on a non-exclusive bases and fo

I confirm that I am the copyright owner of the speci

Signer: 

Name: Dudley F. Giberson, Jr.

Position: Author/ Illustrator/ Inventor

Date: December 3, 2010

On Dec 2, 2010, at 11:15 PM, Heather May wrote:

Dear Dudley,

In June/July 2009 I asked you for your permission to use the above illustrations ' **Volcano Dream**' and '**Generation 3 Bead-maker**' furnaces in my thesis titled **Aesthetic, Creative and Innovative uses for Photosensitive Glass in Art-Glass Production: Case Studies in Studio Practice**. Your replied giving me permission but advised me to write to Krause publishing, 700 E. State Street., IOLA, WI 54990-0001. This I did on the 29th July 2009 but have never had a reply from them. I send the letter by regular overseas mail with my email adress for their reply.

The University would like to you write the following permission:

I hereby give permission for Heather May to include the illustrations of '**Volcano Dream**' and '**Generation 3 Bead-maker**'furnaces for inclusion in her higher degree thesis for the Curtin University of Technology, and to communicate this material via the Australasian Digital Thesis Program. This permission is granted on a non-exclusive bases and for an indefinate period.

I confirm that I am the copyright owner of the specified material.

Signer:

Name:

Position:

Date:

Many thanks for your trouble.

I did not get a moment in the three weeks that I was undergoing a dental reconstruction fy my son, Dr. Jasper Aionoslie of Peterborough in October to come over and see you and show you some of my photographs of my mini furnacee that was inspired by your illustrations because of the pain that I was undergoing. When I next come over to New Hampshire for a visit to Hancock I will certianly come over - no more dental work need now.

Your sincerley,

Heather Ma

P.S. I am days away from my deadline for submission (14th December 2010)!