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A new type of glass furnace. A sustainable future for a threatened creative industry.

In 1995 I attended a talk given by Dan Kline , a renowned glass expert, in which he stated that the studio glass movement was becoming unworkable as a business model.

As a 2nd year student studying glass I was devastated and decided that I would be a glassblower anyway. Whether or not he was right at the time is debatable, but as the years have passed and it has got harder to make a living as a glassmaker, his words have taken on increasingly prophetic meaning.

Since then the British glass industry has been decimated with cheaper and, more importantly, increasingly good quality imports from abroad.

I have spent 4 years as a manager of a glassworks and I can state with confidence that whatever picture society has of the economic standing of British manufacturing, the reality is in fact, far worse.

It is vitally important for businesses to put a 'rosy spin' on their financial position. Any unfavorable information or rumors can fatally undermine a business with banks refusing to support what they perceive as a failing business, and just as damaging, suppliers and vital services refusing to do business because of a fear of non – payment.

I am contracted as a freelance designer for 2 of the last British glassworks still manufacturing tableware. The 2 companies combined employ about 20 glassmakers. As a business they are about the size of a large garage. 15 years ago they employed about 700 people.

As energy costs have increased over the years, small glassmaking businesses are now struggling to survive.

Almost 15 years since I went to Dan Klines' lecture, I have to concede that it is no longer financially viable for a glassblower to start a viable business with the current technology and processes available.

In this talk, I'd like to look at cutting edge technology with my research links at Imperial College of Science and take us on a journey into the past, looking specifically how the industrial revolution changed the way we think about industry as a society. As environmental concerns and sustainability have become more and more important, indeed, essential recently, we must find innovative ways of coping with ever increasing energy costs and dealing with local, national and international environmental concerns. We must of course look to technological advances, but I hope to show that it is just as important that we look at technical and reflective innovation from before the Industrial revolution too.

I have a great deal of experience working with glass and with many different kinds of large and small scale furnaces. I began my career as a craft engineering apprentice at Pilkington Glass working on the maintenance and installation of factory services including the famous float glass furnaces.

On completing my Masters at the RCA I became technical instructor in hot glass and maintained and rebuilt the two highly efficient furnaces designed by Peter Wren Howard.

I've worked on furnaces at Victoria Glass and Simon Moore Ltd in London, and more recently built a ½ ton tank furnace and maintained 2 MRJ furnaces at Teign Valley Glass where I spend 4 years as manager.

I have always been interested in skill and my Masters thesis was on the subject of the acquisition and application of tacit skill.

Glassmaking is a craft. Indeed, any work that involves the performance of a practical skill can be defined as a craft. This would include a surgeon performing an operation, or a scientist performing a practical experiment. The notion of the craftsperson as a quaint or eccentric practitioner is actually a misconception.

What links these practical craft skills is the fact that they are tacit.

Tacit skill is simply the ability to make well. It is the result of experiencing production or repetition of making processes and requires training, commitment and time. The word tacit means 'implied-not stated'. As such, it cannot adequately be defined in words. It applies to glassmaking perfectly because it's very hard to describe in words what we actually do.

A simple example of tacit skill is how we recognise the face of a friend or colleague in a situation such as this. We can all do it. It's easy. But try writing down factually just how we go about this recognition process, without falling back on vague comments like "well I recognise the face". The result will be a complex document. Now magnify that complexity by a thousand and you'll get some idea what it's like to adequately define a tacit skill such as glassmaking.

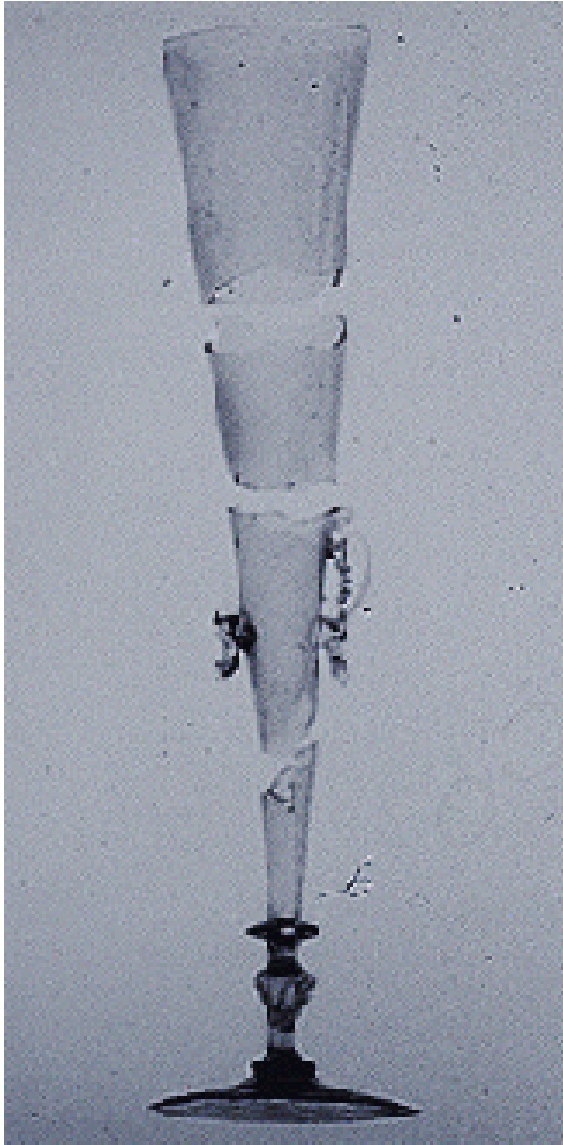
It's essential that we recognise the difference between tacit skill and tacit knowledge. Tacit knowledge is far more complex than tacit skill. When a craftsperson is faced with new situations, we reflect on our experiences and use our skill to devise and implement a plan – a hypothesis to deal with each new situation or problem as and when it arises. In short, when faced with new situations, the craftsperson becomes a researcher in the practical context.

Through my extremely varied experience in industry and education, I have become expert in how glass works, or perhaps more accurately, how it 'feels'.

It was while I was working at the RCA that I accidentally became involved with research. I was approached by Reino Liefkes of the V&A and Dr Sarah Fearn of Imperial College in the summer of 2002. Sarah was working in conjunction with the V&A researching glass conservation using advanced surface analysis techniques in order to find methods of arresting glass disease – the breaking down or corrosion of unstable glass.

My past experiences and knowledge of different glass types enabled me to assist Dr Fearn in melting her experimental glass. She had analysed objects suffering from glass disease and successfully re-created the batch composition.

The 17th century façon de Venise goblet on which replica glass composition was based.



Weight %

SiO ₂	70.60
Na ₂ O	20.25
CaO	2.61
MgO	1.07
K ₂ O	3.68
Al ₂ O ₃	1.10
Fe ₂ O ₃	0.31
MnO	0.37

Sarah couldn't melt large amounts of glass at Imperial College. She had to pour the glass onto a metal plate which resulted in small round pellets that had to be ground and polished to produce the completely flat surface needed for the surface analysis techniques needed. Of course, a cold finished surface removes the 'skin' of the glass, which isn't comparable to a blown glass finish. Also, it is extremely difficult to refine glass in small crucibles even at temperatures reaching 1400 c. One major problem is that the glass seemed to be extremely corrosive and early attempts to melt the batch at Imperial College resulted in failure of the crucible.

I suggested that we put a 25kg crucible into one of the furnaces at the RCA. Our 1st attempt at charging Dr Fearn's glass took place on the 25th April.

We sent samples of the glass batch to Dyson Refractories, experts in the field of manufacturing crucibles, so that the choice of material for the crucible was selected to be specifically resistant to the corrosive nature of that particular batch composition. This is the best match that modern technology could produce. Let's see what happened.

I believe it is crucial that we stop and think for a minute why some of the finest scientific minds couldn't solve the problem of pot failure due to corrosion.

We followed the technical advice, instructions and best practices that are commonly used in industry and the result was a catastrophic failure.



I could see that the failure was caused not by the glass itself, but by the corrosive residue on the surface of the glass. This 'foam' develops as the dry batch material begins to melt.

As I have said, the crucible was chosen by leading experts in the field for its' ability to withstand aggressively corrosive glass compositions. As we can see from these images, the crucible failed dramatically.

Failure was due to the corrosive foam on the surface, not the glass itself. The corrosive foam simply ate through the crucible.

I don't believe that early glassmakers had so much trouble with corrosive glass causing pot failure. Wide clay pots would ensure less contact with the walls, so the corrosive foam would be on the surface. Also, because the crucible was quite literally a pot made of clay, it would have had to have been glazed with a little cullet poured on the inside of the crucible wall before it was filled with glass. This glaze provides protection from the corrosive foam. It's amazing to think that such ancient technology is far more resistant to corrosion than our most sophisticated refractory materials.

I suggested that we try again and attempt to effectively glaze the inside of the pot with 1 hit- filling the pot right to the top in one go. The 2nd attempt was successful and I was able to experience working with a 17th century glass.

This experience left me thinking that 'glazing' the inside of the crucible with cullet, as had been done traditionally, will greatly enhance the working lifetime of modern crucibles. I also felt that it was well worth considering 2 thinner walled crucibles rather than one thick large thick walled 'pot'. This would allow the crucibles to be brought up to temperature much faster than conventional expensive siliminite 'pots'

I managed to solve the corrosion problem simply because after 20 years of working with it, I know about glass as a material. As my skill has increased I have developed tacit knowledge and understanding that enables me to reflect on practical problems and through a complex thought process, put together a hypothesis and a plan, implement the plan and reflect on the success of the outcome. This is a classic example of reflective rationality. It is just as complex as the technical rationality that we use today, but crucially allows us to fill unknown gaps with intuition guided by tacit knowledge.

Reflective rationality was the only mode of thinking available to mankind before the industrial revolution. It results in a 'try it and see' approach to experimentation. All changes were made on the 'factory floor' as it were. The glassmaker was the person who built the furnace and mixed the batch – and this is important – mixed the batch with working characteristics as the main consideration.

Reflective Rationality Before the Industrial Revolution

- Complex practical problems demand specific solutions.
- These solutions can be developed only inside the context in which the problem arises and in which the practitioner is a crucial and determining element.
- The solutions cannot be successfully applied to other contexts but they can be made accessible to other practitioners as hypotheses to be tested."

Altrichter H, Posch P, Somekh B. 1993

Technical Rationality After the Industrial Revolution

- There are general solutions to practical problems.
- These solutions can be developed outside practical situations (in research or administrative centres).
- The solutions can be translated into practitioners actions by means of publications, training administrative orders etc.

Altrichter H, Posch P, Somekh B. 1993

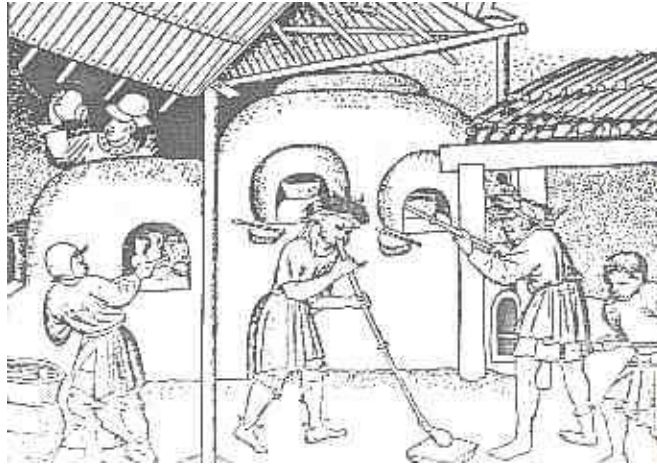
As the industrial revolution swept the country, it became clear that there needed to be a complex managerial and administrative system to be able to cope with the sheer amount of product.

What resulted was the replacement of a hierarchy of credibility with a hierarchy of responsibility. Job descriptions, which have to be introduced as businesses become larger and more complex, are written in words, and therefore can't articulate the tacit skills needed to produce true quality in practice



If we look at the standard set up of a modern small glass studio suitable for one or two sole traders we will see 3 major pieces of equipment – the furnace, which holds the molten glass, the gloryhole, which allows the glassmaker to reintroduce heat to the rapidly cooling glass once it has been gathered, and the lerh, or annealing oven which is a kiln that the finished article must be placed into in order to relieve stress as it cools down to room temperature.

Now let's look back to before the industrial revolution, in fact as far back as the renaissance, and see what kind of equipment we have...

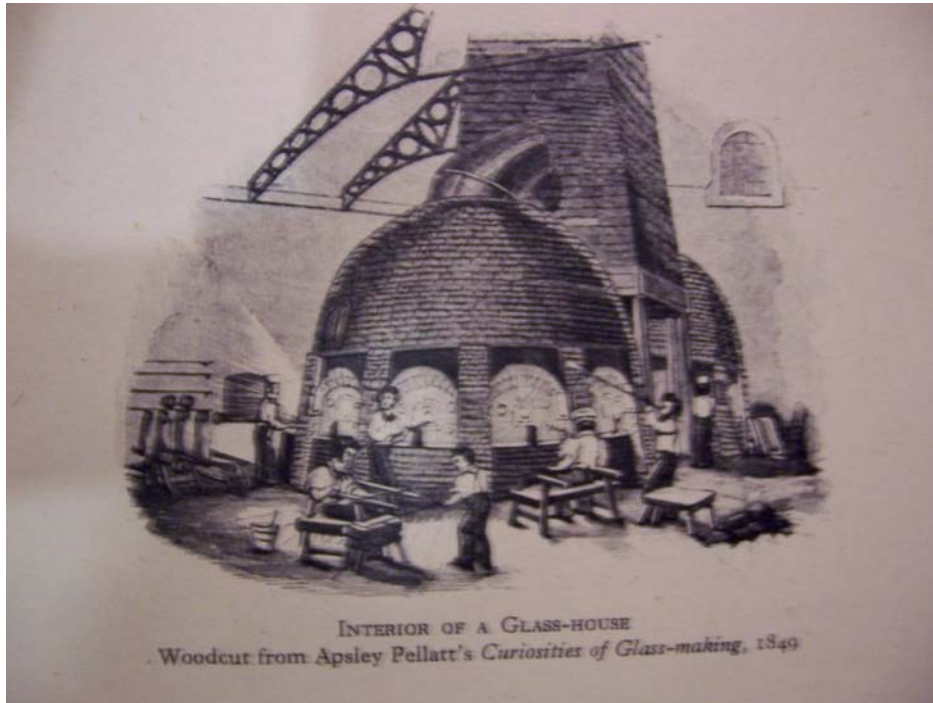


Here we see the glassmaker blowing a vessel. To the right we can see another maker, perhaps an assistant with an iron in the furnace. He could be gathering glass, but if we look closely we see that he is actually looking at the master glassmaker. He is in fact, reheating a piece of glass in the furnace as we would in a modern 'glory hole'.

The guy on the left is vitally important here. It took me ages to find an image of the annealing chamber as part of the furnace. This is the job that our modern lehr/kilns do. The use of waste heat to anneal the glass is what I hope to re-create with modern technology.



Here we see another furnace illustrated in 1668



By 1840, we can see clearly, one of the glassmakers with an iron in the furnace again, looking directly at the master glassmaker.

Some time after this, it became standard practice to have a separate glory hole in factories (This can be seen in the image of a modern workshop above.). This allowed higher temperatures to be reached in the gloryhole without adversely affecting the glass and in turn speeded up production immensely.

We still use this tradition as studio glassmakers, even though it is quality, not speed that is our main concern.

Why?

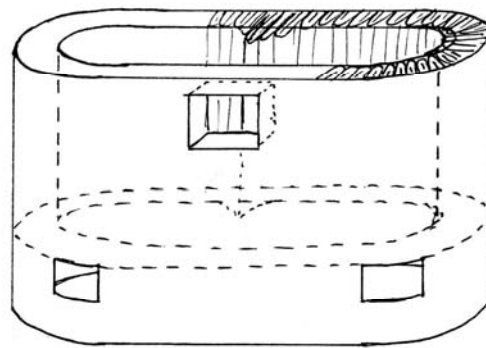
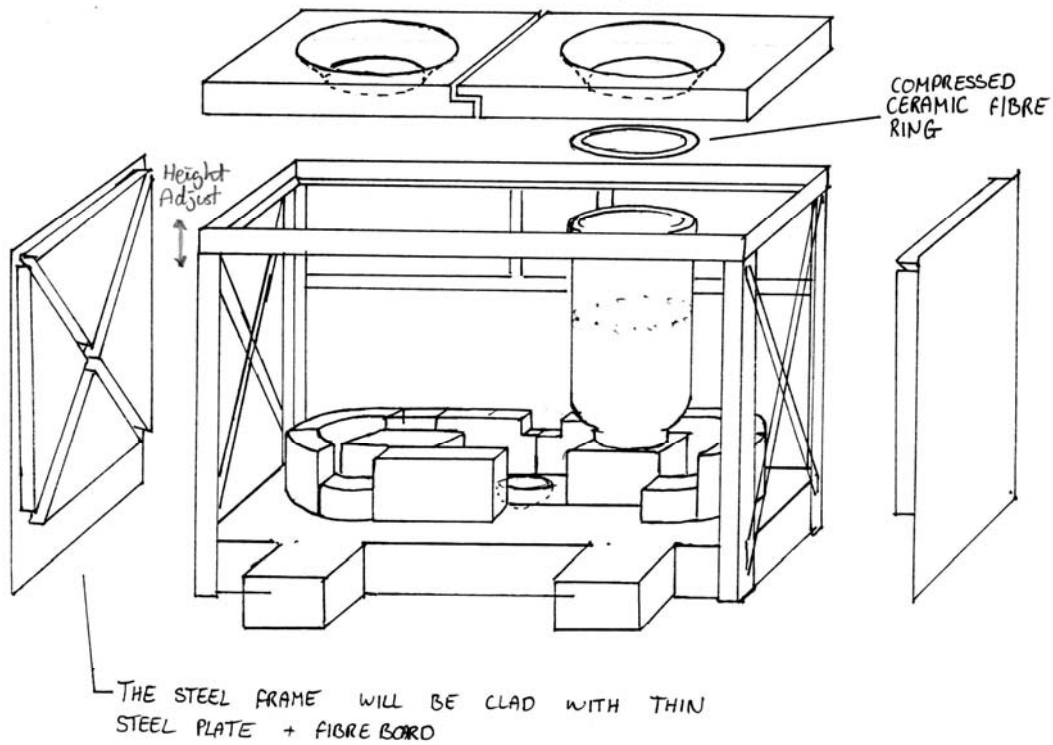
There are many projects looking at ways of conserving energy using recuperated systems and ways of maximizing energy efficiency, but we are still left with these main problems; -

1. A round pot in a square box.
2. Unable to turn furnace on and off quickly.
3. Safe atmosphere requires flue gasses (and heat) to escape easily.
4. Excessive energy costs, increasing rapidly.
5. Competition from imported products from China and India

Once a furnace is lit, it generally stays lit for 6 to 12 months. The larger tank furnace that I've built is designed to stay up to temperature day and night for up to 7 years.

Surely the best way to deal with these problems is to switch the furnace off when it's not in use. This hasn't been possible up to now due to the size and thickness of crucibles and the construction of heavy weight materials within furnaces

I would like to thank Plymouth College of Arts' research committee for funding the 1st phase of this research project.



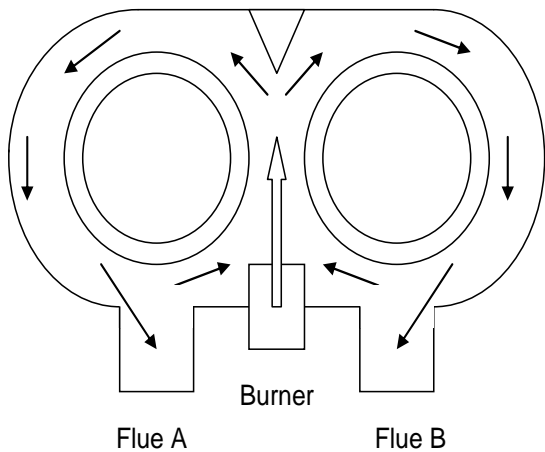
COMBUSTION CHAMBER

Compressed ceramic fibre rings will be used to seal the pot from combustion gasses. This will mean that the heat shouldn't be too excessive when the door is opened. Also, this should protect the fibre construction from glazing which will eat into the fibre blanket.

Using lightweight refractories found in the construction of a glory hole, I'll be building this test furnace over the following 4 months. I've patented the combustion chamber so that I can put the design in the public domain.

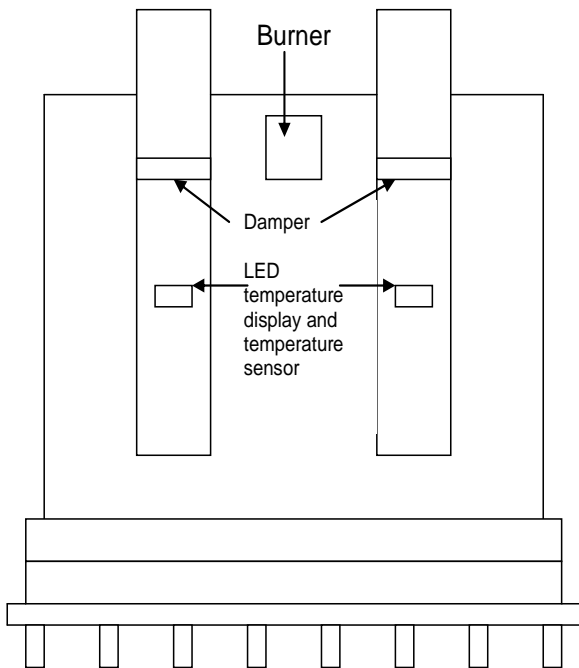
The crucibles hold 25kg each which allows a good days production for a studio maker. I can also have colour melts and experiment with different glass types including recycled glass.

View from top of chamber



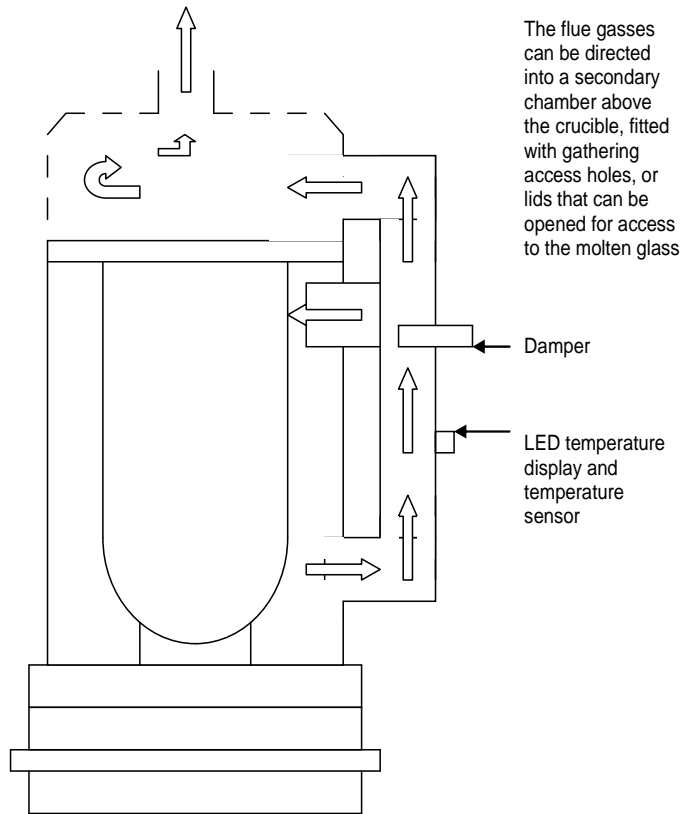
LEFT
The combustion chamber is fabricated from sheet metal. Ceramic fibre blanket is used to insulate the wall of the metal forming a protective insulating layer

BELOW
Flue gasses are directed from the combustion chamber into two flues, each of which is fitted with a temperature sensor and LED temperature display. Dampers fabricated from ceramic kiln shelves are inserted above the LED temperature displays. Moving the damper further into the flue will restrict the flow of gasses on one side of the furnace resulting in a higher temperature reading. Pulling the dampers out will result in a fall in temperature. The dampers will be fitted with restrainers to ensure that they cannot be pushed in so far as they would block the flue and cause a danger. The flue gasses are then directed above the crucible to avoid excessive heat loss.



Back of furnace

The combustion chamber is mounted on a double layer of high temperature insulation bricks designed for use up to 12000 degrees C. These bricks will be mounted on a steel frame



Side elevation

The flue gasses can be directed into a secondary chamber above the crucible, fitted with gathering access holes, or lids that can be opened for access to the molten glass

Damper
LED temperature display and temperature sensor

Here's where it gets really exciting. Once I have built the test furnace, I can use some of the ingenious methods that have been used ages ago to combine all the equipment into one piece of equipment. The glory hole which sits in the corner unused 90% of the time can be situated above this furnace and can provide heat above the crucibles, solving the problem of rapid heat loss when gathering.

It can be open both ends with one end literally inside an annealing oven providing up to half the energy needed to reach annealing temperature.

If we look at the way in which early glassmakers used every ounce of energy to ensure that there is as little waste as possible, we have a good model of sustainable thinking. It took a tremendous amount of wood to produce a very small amount of glass, so the efficient use of energy was of maximum importance. If we add to this way of thinking, access to state of the art and new materials and technology, we have a tremendous opportunity before us;

-a model of working that is not just sustainable environmentally, but financially too.

Using reflective rationality, which was the preferred mode of thinking before the industrial revolution, I strongly believe we can half the cost of running a small glass workshop and produce a viable business model for a threatened creative industry.