

N.B. This is a very rough, preliminary, draft of the book which was finally published as 'The Glass Bathyscaph: How Glass Changed the World' by Profile Books, London, 2002. This draft was completed about nine months before the final book. Many arguments are provisional, the footnotes have not been checked, the order is different. But it does contain many bibliographical details and quotations which were excluded from the final published work. It may therefore be useful for those who wish to pursue the matter further or to know the background to certain statements in the published work.

GLASS AND THE CLASH OF CIVILIZATIONS

In about 1640 the writer Sun Tingquan gave a description of the glass industry at Shandong in his 'Liuli Zhi' (memoir on glass). Sun describes glass-blowing and even the making of filigree glass.¹ But the dramatic change is usually attributed to the Kang Hsi emperor (1662-1722). We are told that he had probably seen examples of western glass brought to his court and 'in 1696 he established as part of the extensive Palace Workshops - the Zaobanchu - a specialized glass workshop to be run, at least at first, by Jesuit missionaries.'² It seems likely, according to the same source, that the techniques used were largely of European origin. Another account places the founding of the workshops 'in 1680 which included clock and watchmakers, enamellers, and a glasshouse', which were 'managed, if not staffed, by craftsmen from Europe, most probably from the Netherlands.'³

What is clear is that quite soon the Chinese were making very beautiful and serviceable objects. As Du Halde put it: 'they imitate, well enough, any Pattern that is brought them, tho' they never saw it before. Thus at Present they make Watches, Clocks, Glass... and several other things which they had no Notion of formerly, or made but very imperfectly.'⁴ Staunton, in his visit to China from 1792 to 1794 described 'how ingenious the Chinese were in producing a glass substitute for a broken place on the top of a valuable celestial globe. He said European workers had been unable to accomplish this...'⁵ We are told that 'Shapes of this period are beautifully simple and typically Chinese: slim jars, usually with slightly bulbous bases, fluted and plain bowls of incredible elegance, simple standing cups, and perfectly plain brush pots.'⁶

¹ Ed Liefkes, Glass, 80

² Sotheby's Encyclopedia, 106

³ Encyclopedia of Glass, 213

⁴ Du Halde, China, II, (xerox), 277

⁵?Xerox, 144

⁶ Encyclopedia of Glass, 213

Recent research suggests that glass in this period was all made in the same area: 'there was basically a single glasshouse or group of furnaces working under the same master craftsman during the latter part of the seventeenth century, and probably the first quarter of the eighteenth.'⁷

After the death of K'ang Hsi and of his son, the Emperor Ch'ien Lung (1736-1795) 'moved the centre of glass production to Po-shan-hsien in the province of Shantung', probably because of the availability of sand and potash there and because 'Po-shan is on the edge of a mountainous area where deposits of coal gave ample fuel for the hungry furnaces, and easily mined deposits of quartz were available to be pulverised and melted into batches of reputedly fine quality glass.'⁸ When the missionary Alexander Williamson visited that area in 1870 he found that glass was 'regarded as an old established craft in the region, with a number of furnaces in and around the main settlement, supplying dealers in Peking with window glass, bottles of various sizes, moulded cups of every description, lanterns, beads and ornaments, as well as rods of plain and coloured glass sold in bulk, presumably for lampworkers and decorative additions.'⁹

The move of the glass factory away from Peking, and the fact that only one licensed area of China probably made glass, explains the account of the decline of glass-making given by Gillan who accompanied McCartney's Embassy at the end of the eighteenth century. He first observed that much of the glass in China was being imported from the West. Trying to account for the superiority of the porcelain (which he was unable to see being made), he noted that in making the excellent blue colours, 'I was informed that they formerly prepared the ingredients for making it from their own cobalt, but now great quantities of smalt (which is the powder of a glass, made from one part of calx of cobalt, usually called zaffre in commerce, and two parts of powdered flint mixed and melted together) are carried out to them from Europe; and of late Prussian blue has been imported for them, which still gives a finer and deeper colour.'¹⁰

What is most startling about Gillan's account, however, is that glass manufacture, according to him, had ceased in China by the later eighteenth century. This is implied by the previous comment on the importing of blue glass and it is amplified as follows (describing impressions in 1793-4) 'There was formerly a glass manufactory established at Peking under the direction of some of the missionaries, but it is now neglected and no glass is made in China.' Yet glass was used. 'The Canton artists, it is true, collect all the broken fragments of European glass they can find, which they pound and melt again in their furnaces; when melted they blow it into large globes or balloons which they afterwards cut into pieces of various shapes and magnitude as they want it. The chief use they make of it is for small looking glasses and a few toys. This is the only kind of glass they now make in China, and as they blow it extremely thin they find it

⁷ Encyclopedia of Glass, 214

⁸ Encyclopedia of Glass, 214

⁹ Encyclopedia of Glass, 214.

¹⁰ Appendix to embassy, 1793-4; s.v. porcelain.

easy to cut with the steel chisels formerly mentioned'. He ends with another fascinating comment on the disappearance of glass manufacture in China. He writes that 'they do not seem to understand the manufacture of glass from the crude materials, nor to know exactly what they are. The glass beads, and buttons of various shapes and colours, are imported to them from Europe and chiefly from Venice.'

Certainly it seems that glass-making had declined again. In 1740 two Jesuits were employed in the Chinese glass-works and supervised the making of large numbers of objects. But after they went, we are told, 'Imperial glassmaking began to go downhill. In the twenty-fifth year [of Qianlong - i.e. 1761] the Emperor asked whether any new missionaries knew how to blow glass. When he learned there was no specialist at the Court, he was very disappointed.'¹¹ There is further evidence cited 'that after the Western experts left, Imperial glassmaking declined in both technical capability and design.'¹²

Another indication of the decline of the making of glass in the eighteenth century is the history of paintings on glass. These paintings became an important and valuable export industry in eighteenth century China, being executed with great skill and artistry on the back of the glass. The technique was again probably introduced by the Jesuits, and the 'plates of mirror glass were imported from Europe for decoration by Chinese painters'. This importation of glass was necessary, for Breton de la Martiniere speaks of Canton as having the only glass house in the Empire. "'Looking glasses and glass mirrors", he writes, "have been manufactured there, quicksilvered in the European manner, but this undertaking has not proved successful. The manufacturers do not know how to manufacture it with the proper materials."¹³ It would be interesting to know more about this and whether any of the flat glass on which most of the paintings were done was made in Canton. The remarks of Gillan above suggest that it was imported glass, re-worked in Canton into new shapes.¹⁴

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It is significant, perhaps, that in his discussion of Chinese science and civilization, Needham failed to discuss the no doubt somewhat exaggerated and self-serving, yet nevertheless largely convincing account of the extraordinary impact of western glass technology and mathematics in the later seventeenth century as summarized by the Jesuit compiler Du Halde. Du Halde was writing in the early eighteenth century and summarizing Jesuit accounts of what happened in the court of K'ang Shi in 167?? (It may be interesting to compare this account with an earlier one from the Chinese side alluded to thus: '... in 1638 Tai Jung wrote the "Chhi Chhi Mu Lueh" (Enumeration of Strange Machines), concerned with the remarkable machines constructed by his

¹¹ ?Xerox, p.144

¹² ?Xerox, 145

¹³ Quoted in Jourdain and Jenyns, Paintings, 35

¹⁴ For a good description of these marvellously accurate paintings, with superb examples, see Carl L Crossman, **The Decorative Arts of the China Trade** (1991), ch.8.

friend Hunag Lu-Chuang. Hunag made and described - or just described - barometers, thermometers, a humidity meter with dial pointers. siphons, mirrors, microscopes and magnifying glasses, various automata, a kind of moving-picture machine...' ¹⁵)

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Du Halde first describes the superiority of western optics. ¹⁶ The curiosity of K'ang Shi led the missionaries to show off their wares. 'They first gave him an Insight into Optics, by presenting him with a pretty large Semi-Cylinder of a very light kind of Wood; in the middle of whose Axis was placed a Convex-Glass, which being turned towards any Object exhibited the Image within the tube in its natural Figure. The emperor was greatly pleased with this Contrivance, which was wholly new to him, and desired that a Machine of the same kind might be made in his Garden at **Pe-king**,For this Purpose they prepared an Object-Glass,they fixed the Ox-Eye, or Glass, directly opposite to the Place... Adjoining to the Base was made a large Closet, or Camera Obscura...'

This was but one of their almost magical displays of what had been discovered in the west. '**P.Grimaldi** gave another Instance of the Wonders of Optics in the Jesuits Garden at **Peking**, which greatly astonished all the Grandees of the Empire. He made upon each of the four Walls, a Human Figure of the same Length as the Wall, which was fifty Feet: As he had strictly observed the Rules, there was nothing seen on the Front, but Mountains, Forests, Chaises, and other things of this Nature; but from a certain Point you perceived the Figure of a Man, handsomely shaped, and well proportioned.'

The part of glass, and particularly mirrors, was especially important. 'It would be too tedious to mention all the Figures that were drawn confusedly, and yet appeared distinctly from a certain Point, or were reduced to order by help of Conic, Cylindric, and Pyramidical Mirrors; together with the many Wonders in Optics, that **P.Grimaldi** exhibited to the finest Genius's in **China**, and which equally excited their Surprise and Admiration.'

Other instruments of glass were also displayed. 'In Catoptrics they presented the Emperor with all sorts of Telescopes and Glasses, for making Observations of the heavens and on the Earth, for taking great and small Distances, for diminishing, magnifying, multiplying, and uniting Objects. Among the rest, they presented him first with a Tube made lie an octagonal Prism, which being placed parallel with the Horizon exhibited eight different Scenes, and in so lively a Manner that they might be mistaken for the Objects themselves; this, joined to the Variety of Painting, entertained the Emperor for a long time. (p.127) They next presented another Tube, wherein was a Polygon-Glass, which by its different Faces collected several Parts of different Objects to form an Image; so that instead of Landships, Woods, Flocks, and a hundred other things represented in the Picture, there appeared a human Face, an intire Man, or

¹⁵ Ronan, Shorter, 1, 257

¹⁶ The following is based on Du Halde, II,pp 126-8

some other Figure in a very distinct and exact manner.'

Another demonstration was as follows: 'they shewed him a Tube with a Lamp in it, the Light of which came through a little Hole of a Pipe, at the End whereof was a Convex-Glass; then moving several small Pieces of Glass, painted with divers Figures, between the Light and the Glass, the Figures were thrown upon the opposite Wall, appearing either very large or small in Proportion to the Distance of the Wall; this Spectacle in the Night, or in a very dark Room, frightened Persons ignorant of the Artifice ... on which Account the name of the magic Lanthorn was given to it.'

Particularly interesting was a demonstration of how reliable knowledge about the natural world, had made accurate representations of three-dimensional space possible in western Europe in a way which was lacking in China (as well as Japan, India and Islam). 'Nor was Perspective forgotten: **P.Bruglio** gave the Emperor three Draughts performed exactly according to rules, and he hung up to View three Copies of them in the Jesuits Garden at **Peking**. The mandarins, who flocked to this City from all Parts of the Empire, came to see them out of Curiosity, and were all equally surpriz'd at the Sight; they could not conceive how it was possible on a plain Cloth to represent Halls, Galleries, Porticos, Roads, and Avenues reaching as far as the Eye could see, and all this so naturally as at the first View to deceive the Spectator.'

All this superior technology was, along with mechanical clocks and other gadgets, extremely useful for the Jesuits in winning access to the Emperor. 'Whenever any extraordinary Phaenomenon, such as a Parhelion, Rainbow, Halo of the Sun and Moon, &c. appeared in the Heavens, the Emperor immediately sent for the Missionaries to explain the Causes of them.' They then 'composed several Books concerning these natural Wonders' and furthermore invented new devices incorporating glass to illuminate their knowledge. Thus 'to support their Explications in the most obvious Manner, they contrived a machine to exhibit those Appearances in the Heavens. This was a Drum, made very close without, and whitened on the in-side, the inward Surface of which represented the Heavens. The Light of the Sun entered at a small Hole, and passing through a Triangular Prism of Glass, fell upon a little polished Cylinder, by which it was reflected upon the Concavity of the Drum, and there exactly painted all the Colours in the Rainbow, marking at the same time the Parallel, which the Sun moved in the Day. From a Part of the Cylinder a little flattened, was reflected the Image of the Sun; and by other Refractions and Reflections were shoven the Halo's about the Sun and Moon, with all the rest of the Phaenomena relation to celestial Colours, according as the Prism was more or less included towards the Cylinder.'

Nor was it just instruments of vision which were displayed. 'They likewise presented the Emperor with Thermometers, to shew the several Degrees of Heat and Cold. To which was added a very nice Hygrometer to discover the several Degrees of Moisture and Dryness....' The conclusion of all this was very gratifying for the missionaries for the Chinese were checked in their sense of superiority. 'All these different Inventions of Human Wit, till then unknown to the **Chinese**, abating somewhat of their natural Pride....'

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What is more difficult to prove, though at a very general level it seems so obvious, is the way in which this contrast in the availability of scientific instruments made with glass affected knowledge at the two ends of Eur-Asia, both in what we call 'science' and in 'art'. The description by Du Halde gives us some clues. The Jesuits used some of the glass instruments to show how their knowledge was greater. They did this not only in the ways described above but also at some length in proving that their astronomy was superior.¹⁷ Du Halde implies that mathematics was far less developed than in the west, perhaps somehow related to their backwardness in optics. 'As for their Geometry, it is superficial enough; for they are very little versed, either in the Theory, which demonstrates the Truth of Propositions called Theorems, or in the Practice, which teaches the method of applying them to Use by the Solution of Problems.' As for the 'other Parts of Mathematics, excepting Astronomy, were entirely unknown to the **Chinese**; nor is it above a Century since they began to perceive their Ignorance upon the Missionaries first Arrival in **China**.' He also implies that the mathematics embedded in the visual arts was related to glass - the sense of perspective etc. All this is fascinating, if over-drawn.

Yet immense as the implications are of what he wrote, as we have seen, these aspects of glass are only part of the picture. Du Halde hardly alludes to many other important developments. The direct implications of the telescope on astronomy is not mentioned, though it is implied. The implication of microscopes is overlooked. The effects of glass on chemistry is not mentioned. Nor is he able to address the question of what had happened to reliable knowledge in China in the preceding centuries. There is the curious fact that while the Chinese made very considerable advances in optics very early on, reputedly reaching a similar level of sophistication and knowledge as the Greeks by the thirteenth century, they halted there. They did not then make the break-through which was achieved first in Islamic optics and then transferred and built on in western Europe. So recent authorities conclude that 'ancient Chinese optics' was 'based on empirical observations, which was short of theoretical abstraction and quantitative description.' Consequently when the fruits of the Arabic and Western optics, based on experiments with glass, were introduced to China from the seventeenth century 'the entire foundation of traditional Chinese optics was changed.'¹⁸

This is, at present, speculative. It is merely to suggest that without microscopes, telescopes and all the other tools, China was caught in this natural world. Precision eluded the greatest minds; they stayed on the surface of things. And they did this through a giant accident. The west developed glass for other purposes, for luxury, beauty and comfort. They then found it good to think with. India, China and Japan found their luxury, beauty and comfort in other materials, cheaper and just as beautiful. Yet pottery and porcelain do not have the same optical properties

¹⁷ See Du Halde, pp. nXXX for a good account.

¹⁸'Optics in Chinese Science' by Jinguang Wang and Caiwu Wang, in **Encyclopedia of the History of Science...**, p.795

as glass and hence cannot be turned into powerful stimulants to human sight and thought, extensions of man's most reliable and penetrating sense organ, the eye.

The impact of scientific glass in Japan

The impact of western glass technologies is given a further depth if we look at one further case, Japan. This basically shows three things. Firstly, it confirms the absence of scientific glass in China up to the arrival of the Jesuits. Japan was largely dependent on China for its technology, but usually quick to emulate it. If there had been glass instruments on a wide scale in China, they would have been imported. The very late impact of western glass, coming through the Dutch rather than China is further evidence, if it is needed, as to the non-development in China.

A second inference is the way in which it takes more than artefacts to change a knowledge culture. In China the impact of the Jesuits with their marvels was almost nil; the clocks and glass tools were kept as curious museum pieces and had hardly any impact for several hundred years. Yet, as we shall see, the Japanese, who for centuries had been keen to import new ideas and technologies from their giant neighbour and Korea, were fascinated by western glass instruments and very rapidly absorbed them and altered their world of knowledge very quickly.

Finally, the case of Japan has recently been minutely examined specifically in relation to scientific instruments of glass. This well documented case gives us the opportunity to see some of the deeper ways in which a gradual, and hence largely invisible process of knowledge accumulation in the west, occurring over hundreds of years, made a difference. The encounter was sharp and relatively short and some of its salient characteristics therefore stand out. The encounter also reminds us, if we need such reminding, that the non-development of glass has nothing to do with technical ability. As soon as they saw a use for it, as had earlier happened with guns, the Japanese made excellent glass for many purposes.

The technical ability was such that when necessary the Japanese could apply it to any purpose. For instance the making of scientific instruments, when required, was no problem. In the 1790's Thunberg observed that 'In like manner they understand the art of glass-grinding and to form Telescopes with it, for which purpose they purchase mirror-glass of the Dutch'.¹⁹ By the 1850's, at the time of Elgin's mission, Oliphant noted that 'At Nagasaki, the result of intercourse with Europeans for two centuries and a half is very apparent. There were to be seen admirable telescopes of native manufacture, clocks, magnifying glasses, and glass ware of various descriptions...'

As for microscopes, this was according to Screech 'generally recognized as the symbol or hallmark of **Rangaku** [Western] scholarship.' Screech believes that 'The first microscopes may have been imported into Japan early in the eighteenth century or even before...', but by 1765

¹⁹ Thunberg, *Travels*, iv, 60

people were writing enthusiastically about the new microscopes with magnification of over one hundred times.²⁰ Churyo in 1787 wrote as follows: 'Recently a lens for detailed viewing called a **mikorosukopyumu** arrived from abroad... We brought several things into focus and inspected them under it. The clarity of the minutiae was quite extraordinary. Salt crystals could be seen to have a hexagonal shape while buckwheat flour (even the most finely sifted sort) was triangular. A candle wick looked like a loofah and mould was shaped like mushrooms; water was like hemp leaves with patterning on them, ice had a warp-and-woof design; sake was like boiling water, all seething in bubbles...' As Screech comments, 'The microscope fascinated to a degree that in the blase late-twentieth century we cannot readily appreciate. The visions were novel to the point of inspiring disbelief.'²¹ Screech further comments that the 'microscope stands for an alternative epistemology, that of science with its claims to understand by opening up and seeing, and classifying the world into taxonomic plots.'²² And furthermore, commenting on the teeming life discovered in a drop of water by van Leeuwenhoek in 1683, Screech notes that 'The discovery of warming collectivities within ostensibly unitary entities was one of microscopy's most salient revelations.'²³

Screech suggests that 'in Japan Ownership became so widespread that a how-to manual was issued for the amateur user ... in 1805', and that for 'those short on silver, microscopes were also set up at roadside fairs, usable by all'.²⁴ Yet it seems that they remained fairly restricted. The zoologist Morse, noted in the 1870's, 'They had never before heard of a microscope or a spy-glass. If they had ever seen an object magnified, it might have been through a burning-glass, though I have never seen one in Japan. Doubtless they have them, as the Chinese use them.'²⁵

Another use for glass is in chemistry. Screech describes how in eighteenth century Japan 'More malleable than ceramic, glass was also ideally suited to fashioning the strange retorts, twisting alembics, and variform dishes required by the eighteenth-century scientist. These, too, were introduced, and filtered into the studios of **Rangaku** scholars.'²⁶ Screech notes that 'Glass also offered a long-term store for objects and was useful for the experimentalist. Because of its see-through qualities, samples that had to be inspected but not disturbed could be conveniently housed in bottles, and monitored or subjected to various conditions. Technical-looking vessels were generically called **furasuko** (flasks), whereas goblet shapes were **koppu** (cups).'²⁷ He quotes a nice passage by Otsuki Gentaku as follows. "Initially, the

²⁰ Screech, Western, 194

²¹ Screech, Western, 194

²² Screech, Western Gaze, 202

²³ Screech, Western, 208

²⁴ Screech, Western, 198

²⁵ Morse, Day by Day, i, 235

²⁶ Screech, Western, 136

²⁷ Screech, Western, 137

material was enjoyed just for its sparkle and shine, but of late it has been recognised that glass ought not to be limited to use in playthings. Jars and bottles have been made, and things stored inside them. When so kept, a material's original characteristics (**honsei**) are preserved indefinitely; medical substances or fragrances can be passed on like this over long periods.²⁸

Finally there is the important topic of spectacles. Screech writing of the later eighteenth century notes that 'Glasses had existed in Japan for some decades, and the first pair were said to have been given to Tokugawa Ieyasu by the Europeans at the turn of the sixteenth century. Glasses sellers began to be a regular feature of Edo-period life only some hundred and fifty years later, although throughout there would still have remained plenty of people who knew them only by repute.'²⁹ Mitaku Yorai in 1732 in an encyclopedia described how glasses "'are about 3 mm thick and look like the chopped slices of giant radish."³⁰ The author described, in Screech's words, how 'Rough-and-ready spectacles made of crystal and suchlike were constructed in Japan... and were used by the weak-eyed, the elderly, or those engaged in intricate work (swordsmiths, seal carvers, inlayers) (Fig. 27) But these would not have been pleasant to use, being ponderously heavy while offering a magnification that was not very great.' Yorai noted that while now made in Japan, "in former times they came from China".³¹ But the lighter and better glass ones were coming from the West.

Screech writes that 'Already by the seventeenth century the import of spectacles was accounting for fully one per-cent of the total value of the Dutch-Japan trade: in 1636 this represented 19,425 pairs sold, a figure that nearly doubled the following year, to 38,421...'³² During the eighteenth century specialist opticians opened in Japan, 'one famous establishment being the Murano-ya in Akasuka, near the Temple of Kannon.'³³ This shop stocked "Dutch glass goods", including 'all manner of glass objects: telescopes, flasks, wine glasses, mirrors, and mirror pictures', many of which were made locally, Screech thinks, though 'not the glass lenses which could not be ground locally'.³⁴ Almost all lensed instruments were called **megane**, and these included "blindness-curing **megane**" with medicine added and "literacy **megane**" for those who had not been taught to write, 'made by mashing up old books'.³⁵

We are told that 'Glasses, being imported, were not to be had on a bespoke basis but were bought off the peg. They took scant account of individual requirements or astigmatism. The preponderance were only mildly magnifying and not for regular use, but were donned as

²⁸ Screech, Western, 137

²⁹ Screech, Western, 181

³⁰ Screech, Western, 181

³¹ Screech, Western, 181

³² Screech, Western, 181

³³ Screech, Western, 182

³⁴ Screech, Western, 182

³⁵ Screech, Western, 183

required to perform special tasks.³⁶ Hardly anyone wore them the whole time, one exception being a Dutch captain.³⁷ Screech suggests this is because 'Through-the-lens vision was no right-thinking person's normal gaze, but, rather, a uniquely eloquent restructuring of sight temporarily directed towards a particular end.'³⁸ Glasses made it possible to gaze very directly. 'Perhaps it was for this reason that eighteenth-century Korean children were forbidden to wear glasses in front of their parents, the piercing gaze of the wearer being considered simply rude.'³⁹ People wore glasses for all sorts of social and other purposes, and consequently, Screech argues, they were 'generally considered neither medical equipment nor scientific instruments, but trappings. The **Universal Encyclopedia** put them in the personal accessories section (**fuku-gangu**), lumped together with fans, back-scratchers, and hanging pockets (**inro**)...' Thus they easily declined into 'affected folly'.⁴⁰

Standing back from the details, Sugimoto, a historian of science in Japan, is right in seeing the development of scientific instruments in Japan as basically occurring without glass. 'Actually, the Japanese did produce the magnetic compass, quadrant, astrolabe, and mechanical watch... Japanese products had not glass covers; there was no ordinary use of glass in Japan in the premodern period.' (Sugimoto, *Science*, 181)

³⁶ Screech, *Western*, 185

³⁷ Screech, *Western*, 187

³⁸ Screech, *Western*, 188

³⁹ Screech, *Western*, 188; cf. the piece in Ball, *Things Chinese*, which suggests the same in China.

⁴⁰ Screech, *Western*, 189