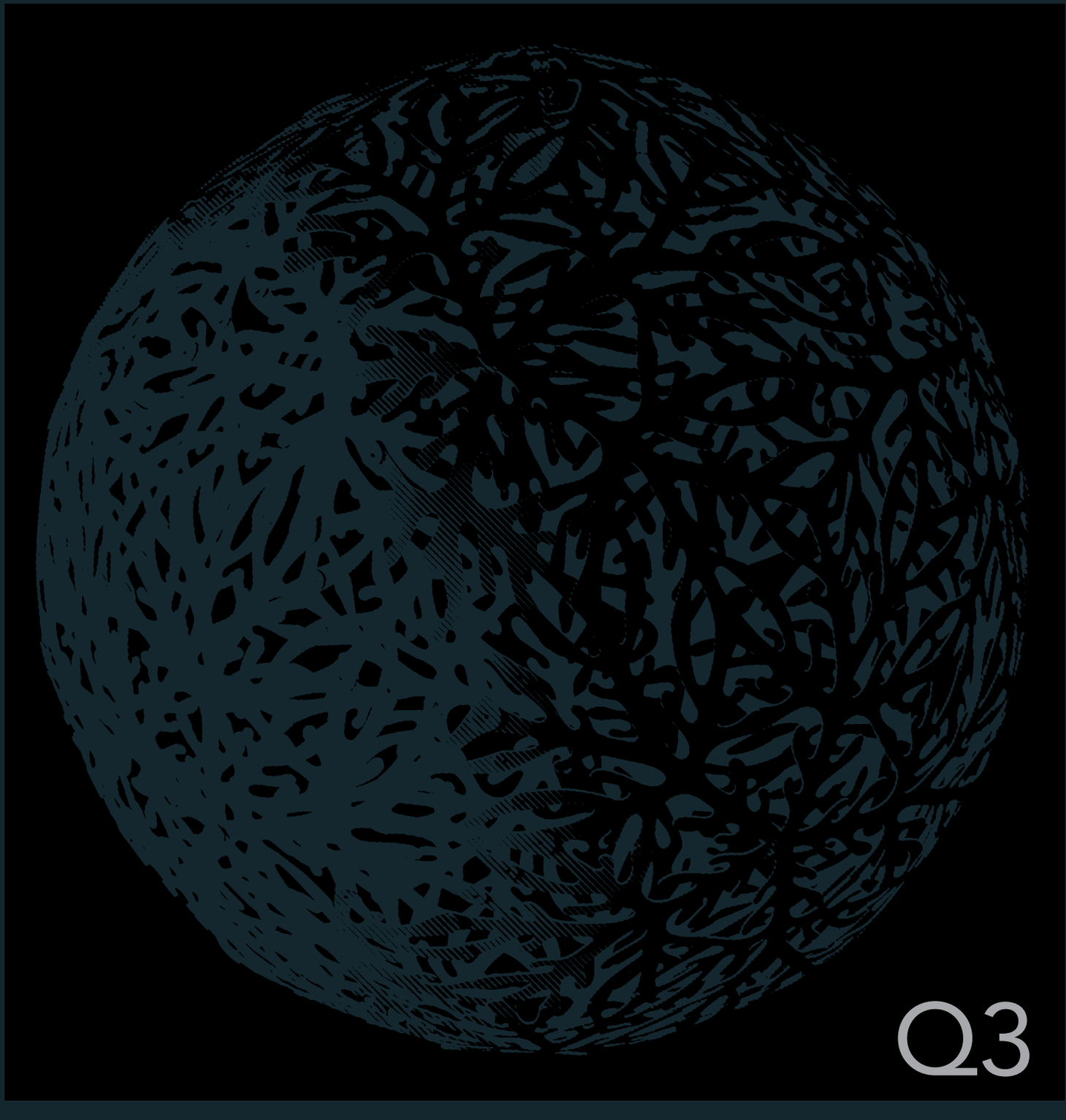
SUPERYACHT DESIGN

INTERIORS ■ DESIGN ■ EXTERIORS ■ ARCHITECTURE ■ SPACE

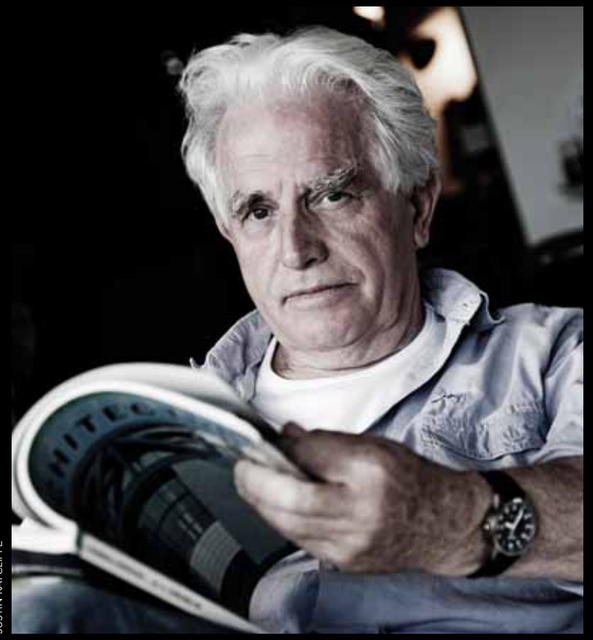


SUPERYACHT
DESIGN

SOLID LIQUID

In theory at least, glass is visco-elastic and not a solid substance. It also happens to be very strong—stronger than many metals—making it a safe and versatile structural material. Yet although land-based architects have been innovating with glass for decades, the yacht building industry has been slow in catching up. SYD investigates a see-through world that has yet to be fully exploited.

JUSTIN RATCLIFFE



JUSTIN RATCLIFFE

MARTIN FRANCIS

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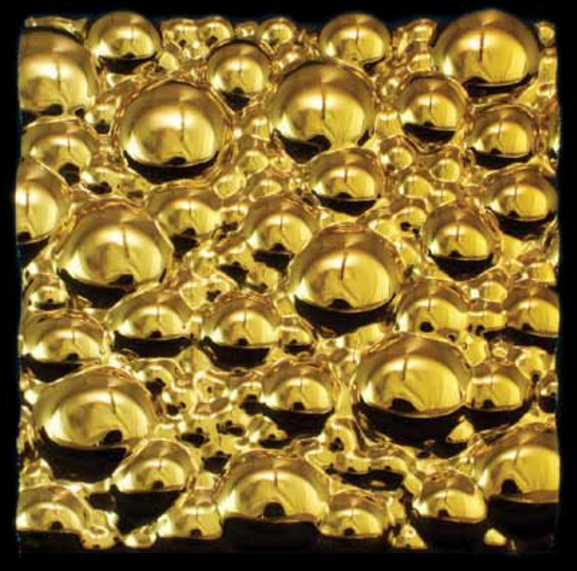
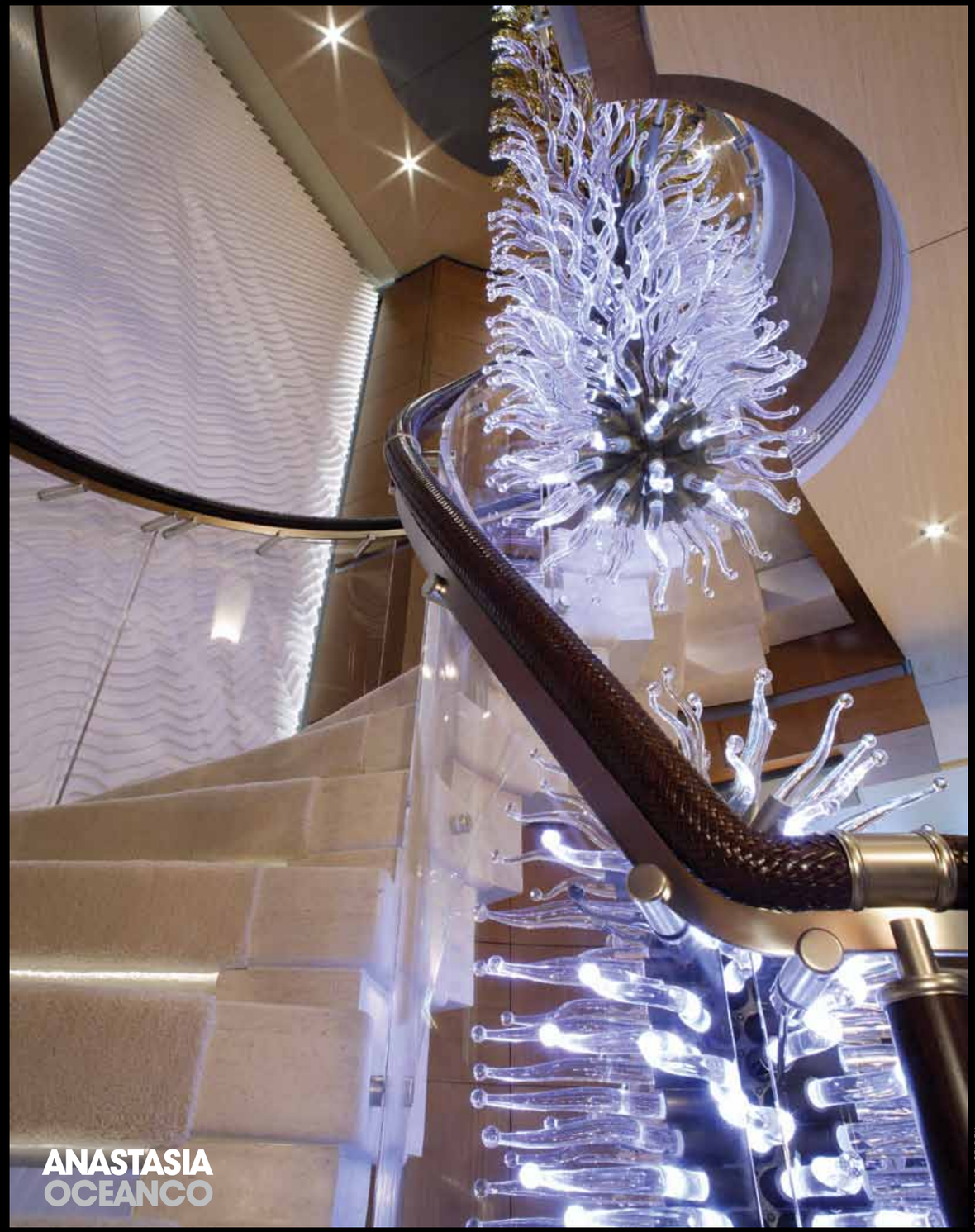


Facing page: clockwise from top left: Martin Francis; his Sultan 126 concept was developed from the iconic curved windows of *Eco* (bottom).

Clockwise from below: three glass sculptures by Czech artists (Vasicek, Frydrych, Rybak) and glass tiles by Crystal Caviar.

CRYSTAL CAVIAR



ANASTASIA
OCEANCO

OCEANCO / B. GELDEK

LURSSEN / KLAUS JORDAN

Martin Francis is widely considered the guru of glass in superyacht circles. And for good reason. He began his career as a furniture designer and cabinet maker, but quickly moved into architecture when he collaborated with Norman Foster on a number of groundbreaking projects in the '70s such as the Willis, Faber & Dumas head office in Ipswich. By adapting so-called 'patch' fittings developed by the glass manufacturer Pilkington (the inventors of float glass), Francis devised a cladding system for the building by which enormous panes of toughened glass were suspended by a single bolt.

A decade later Francis joined forces with Peter Rice and set up RFR, a consultant engineering firm in Paris. Together they advised on the glass structures of the Museum of Science & Technology in the French capital, for which they perfected and patented a bolt mechanism inspired by the self-steering gears he had designed for yachts this featured a ball joint that allowed the glass to deflect without the fixing generating a bending moment under wind load. This later led to work with I.M. Pei on the famous glass Pyramid in front of the Louvre, for which he recommended Navtec rods instead of cables to support the structure, much like the rigging of a yacht. Intriguingly, Tim Eliasson who founded Navtec, went on to set up TriPyramid Structures, Inc. to pursue further the architectural applications of tension structures and today the company is playing an active role in imaginative architectural projects.

It wasn't until Francis designed his first motoryacht, however, that he was able to put his knowledge of glass into practice in a marine context. *Eco* (later *Katana* and *Enigma*) was built for the Mexican media magnate Emilio Azcarraga by Blohm & Voss and launched in 1991. Driven by gas turbines and capable of speeds in excess of 35 knots, the 74-metre vessel was at the cutting edge of yacht engineering technology. But it was *Eco's* radical exterior design that really got her noticed. Francis specified curved glass throughout the superstructure—a solution that is as innovative today as it was then. Francis recounts the story of how it came about:

"I'd been working on the project for a couple of years for Azcarraga. He had owned two radical Bannenberg yachts, *Azteca* and *Paraiso*, and wanted the same military styling. In the end, we weren't getting any closer to a final solution, so Azcarraga told me to get some other people involved. Amazingly, I was requested to subcontract both Bannenberg and Giugiaro, the Italian car designer, to do some styling studies. Both came up with schemes that were eventually rejected by the client, who then said he was interested in buying *Carinthia VI*. That got me thinking, because we'd been working on a brief for a 60-metre yacht with faceted styling and now he was looking at a 72 metre. So I went back to the office and said, 'let's start over again, and forget the brief.' The idea for *Eco's* curved windows came from the windshields of Parisian buses, which are designed to reduce internal reflections. It seemed like an interesting thing to try and I made a full size mock-up on the roof of my house. We had the final showing in Palma where we showed the owner a presentation with various overall lengths and the same superstructure, they looked much better at 72 metres. He took one look and said, 'That's the boat I want, if you can build it to the right price.'"

A German subsidiary of Pilkington, ironically called Flat Glass, was contracted by the builders Blohm & Voss to make the curved panes using simple toughened glass. Adco Technik GmbH, another leading glass manufacturer, was also consulted and installed the all-glass fitness room aboard the yacht (the Rostock-based company specialises in marine projects and has supplied several megayachts, including *Al Mirqab, Rising Sun, Limitless, Kismet* and *Skat*).

"Glass is incredibly strong in compression and very weak in tension", explains Francis.

Below: these lamp shades aboard *Kokomo* were made from recycled glass bottles.

"Toughening glass by heat is not unlike tempering steel and overcomes this weakness. The glass is heated to a semi-plastic state and then chilled very quickly with cold air. The outer skins harden to form a crust, while the inside cools slowly and shrinks, putting the outer skins into compression. So when you bend the glass like a beam you have to overcome the pre-stress or compression in the bottom half of the beam before it breaks."

To create the curves the glass is heated then passed between two matching moulds to deform it into the desired shape (about a third of a circle). When the moulds were pulled apart, a bank of air jets shaped to follow the exact same curvature, cool the glass uniformly. Therefore the initial tooling was hugely expensive as different moulds were required for each size of glass. In fact, Francis remembers the final cost of each pane was around 6,000 deutschmarks or roughly 3,000 euros—a considerable sum 20 years ago and perhaps one of the reasons why *Eco* has never been emulated, despite the fact that modern chemical toughening and more recent bending processes are less costly.

"The idea for *Eco's* curved windows came from the windshields of Parisian buses..."

"The moulds at the time were made of wood with little screw jacks to adjust them like the staves of a barrel", continues Francis. "I calculated that we needed at least one spare piece of glass for each pane because they were going to destroy the moulds. To this day—touch wood—none of the spares have been used."

Having managed to make the panes both curved and distortion free, the next challenge was to prove to the Lloyd's surveyors that they were strong enough for the job as storm shutters could not be fitted to the rounded windows.

"We did finite element calculations based on a worst case scenario of asymmetric loading if a wave went over the foredeck and wedged itself under the bottom of the glass", continues Francis. "Lloyd's accepted our calculation, but required additional storm mullions that could be fitted in ▸

place from the inside, which have never been used. Because of her low freeboard in the bow, we also designed a wave breaker and a foredeck locker that acts as a buffer to redirect green water into the centre of the curved glass at its strongest point."

Eco was effectively a massive experiment from start to finish, made possible only by an enlightened owner who was willing not only to foot the bill, but also to place his faith in both designer and builder. The result was a master lesson in glass architecture and aesthetics that the superyacht industry has been slow to take on board. An exception has been Luca Bassani and abundant use of glass has been a key feature of Wally Yachts from the start. The WallyPower 118, in particular, was the first yacht in 2003 to feature an all-glass superstructure that fully exploits the outside-inside living concept by providing panoramic views of the surrounding sea and landscape. The laminated glass panels are glued to the carbon frame and UV filters screen the sun's brightness and heat so guests don't cook on the inside.

When it was first presented at the 2006 Monaco Yacht Show, Feadship's X-Stream concept attracted attention for its all-glass, domed superstructure. How the dome with its triangular glass panes supported by an aluminium framework would be built was the subject of ongoing research by the design team, headed by Chris van Hooren, who consulted aluminium manufacturer Alcoa and various glass suppliers. The structure was inspired by a publication entitled *Twist and Build. Creating Non-Orthogonal Architecture* by Delft University architect Karel Vollers. However, the design created a whole host of problems associated with keeping the dome clean and maintaining a constant temperature in addition to the sheer weight of the glass.

Ken Freivokh is another designer who is challenging conservative opinions about how glass can or cannot be used in yacht design. He is working on interior concepts for a 55-metre Heesen developed from glass atrium aboard *The Maltese Falcon* in which an enormous skylight and cylindrical glass elevator shaft occupies the space where the mainmast used to be, providing natural illumination through all the deck levels.

Martin Francis himself followed up *Eco* with the even more stunning Sultan 126 and proposed a massive all-glass superstructure with the futuristic, 140-metre Crystal Ball concept for HWD. Sadly both projects have yet to be realised.

One difficulty with glass is that it is 'statistically non-determinate', which means very occasionally it will spontaneously fracture. This was discovered in the early days of toughened glass, but no one knew quite why. It was later found it was caused by microscopic metal inclusions in the glass. So a process called 'heat soaking' was devised that rapidly heats and then cools the glass, which will break if there is a defect in it. When Francis is writing up a spec for glass, he always insists that it should be tested by heat soaking.

"The point I want to make is that glass is an engineering material like any other", urges Francis. "Just look at all the Apple Stores with their glass staircases and bridges, for which Steve Jobs holds patents. The classification societies haven't quite got to that stage yet, but they can be taken there. They require that the glass is the same strength as the steel or aluminium around it, and you can easily demonstrate that mathematically. We have to de-mystify glass. There is no reason why we can't have a completely glass superstructure like the Crystal Ball. When you look at filling and fairing, it costs a fortune. So why not make the whole superstructure out of glass? It's got no paint, its self-finished, its chemically inert, weatherproof and you can wash it."

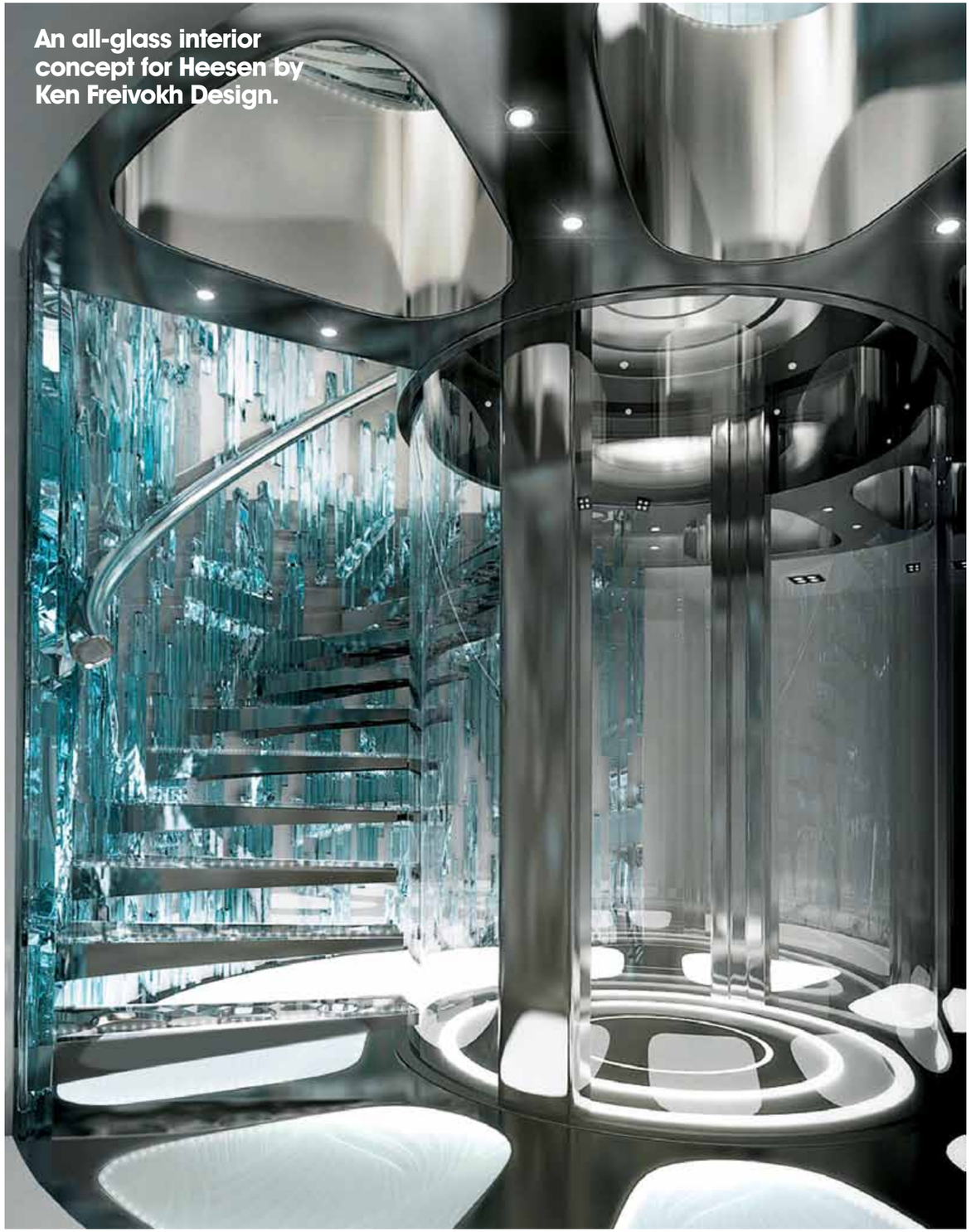
There is the issue of how to clean such a huge expanse of glass, but Francis focuses on another point that he feels does not receive adequate attention: how glass windows aboard yachts are fixed in place.

"The main problem is that they're not looking properly at the frames and how the glass is held in. The classification societies want both adhesive and mechanical fixing, typically many yachts have cast aluminium frames—not forged or extruded, so they're weaker—and stainless steel screws. If a big wave hits the window all the loading goes onto the screws and thread, which is easily stripped. In addition, you may get a bi-metallic corrosion so after a few years it's a fizzing mess. It may be approved, but to my mind it's complete nonsense. Glues are sufficient: the automobile industry uses them and so do cruise ships. In architecture the glue absorbs much of the distortion and prevents the loading going through to the fixings. When we were researching the Science Museum, we hung two tons of glass in a test frame outside the Rhône-Poulenc facility near Lyon using only their silicone adhesive to support it. The loading was something like 45 kilos per linear centimetre and to the best of my knowledge it's still standing after 25 years."

"...why not make the whole superstructure out of glass?"

If the potential of glass as a structural material is only gradually penetrating the yacht building industry, as a decorative medium it has always been popular. Glass screens, wall sconces, chandeliers and sculptures are increasing both in terms of size and creativity. A classic example is 75-metre *Anastasia* designed by Sam Sorgiovanni and launched by Oceanco in 2008. In the main stairwell hangs an enormous eight-metre high glass chandelier designed to resemble kelp that was made by the Czech artist Rybak.

The piece was supplied by Sans Souci and project managed by the former head of its yacht division Marek Landa, who has since founded his own company called Crystal Caviar. Based in northern Bohemia in the heart of the Czech Republic's glass-making region, Crystal Caviar produces its own glassware and represents other artisans and is currently working on commissions for three yacht projects over 100 metres. Landa, not unlike ►



An all-glass interior concept for Heesen by Ken Freivokh Design.

KEN FREIVOKH DESIGN

Martin Francis, has an eclectic background with a degree in Business & Environmental Studies from Salford University in the UK. He is also a Class 4 engineer who has worked on several large yachts, an experience that makes him uniquely qualified to supply the superyacht industry. A visit to the Crystal Caviar showroom in an old abandoned factory that Landa is renovating, revealed some remarkable glass pieces, such as the pearl-like pebble tiles that took two years of trial and error to perfect.

"It was thought impossible to meld together glass globes or pebbles and retain their shape", explains Landa. "We've spent a small fortune on the research and the first attempts kept cracking from the inner tension. Now it behaves like solid glass and is completely safe. We have a version that stays longer in the oven with a slower cooling curve to make the glass less porous, so when grouted properly with silicone it's suitable for tiling Jacuzzis or swimming pools."

In fact, around 100 square metres of these pebble tiles were used to line the base of the fountain aboard Royal Caribbean's *Oasis of the Seas*, the largest cruise liner in the world. Besides the pebble glass that can also be curved to make wall sconces, Landa showed me examples of twisted glass rods that can be used for handrails and chandeliers, or fused with sheet glass to create screens and partitions. As they have a hollow core, LEDs can be inserted for illumination or a metal spine to produce continuous lengths. Ice glass, so called because it resembles the patterns created by heavy frost on windows, is a traditional technique that has been resurrected by Landa and involves gluing small pieces of wood to the glass then stripping them off to remove fine splinters of glass. Another Crystal Caviar novelty is luminescent glass that continues to glow after the light source has been turned off, ideal for subtle way marking aboard a yacht at night.

"When you combine two or three techniques you already have something different", says Landa, who believes the full potential of decorative glass has yet to be realised. "We work more like a guild with different studios working on the same project. So if we have a glass partition it will combine cast pieces, which are then glued and acid etched, engraved and painted, then re-heated in the oven. Another technique is gilding with titanium, gold or silver, or even inserting aluminium kitchen foil. The techniques themselves are widely known, it's more about combining several processes. A jewellery technique, for example, when applied to an artwork or partition will produce a different effect because it's on a much larger scale."

As way of an example, Landa singled out the blown glass wall sconces aboard *Anastasia*. These were etched, engraved and sandblasted on the inside surface with marine motifs. With each process, the danger of the glass breaking increases (of the 16 pieces attempted, only eight survived to be installed). This reveals another aspect of the glassmaker's art, one that is not fully appreciated by owners and designers when ordering custom pieces: glass making is a long and laborious process and fraught with the prospect of failure. Glass has to be heated in the oven at a rate of about 5°C per day to at least 800°C, so large quantities can take weeks to melt and just as long to be 'annealed' or cooled down again, while cracking is a constant concern.

"Quality glass is expensive because it can take weeks or months to produce the larger custom pieces", Landa points out. "Then if it cracks in the oven, you have to start over again. If you're pricing wrongly it can be a losing business, so it's very difficult to talk about margins with artworks. It's all about long-term pricing, but the ready-made pieces are generally cheaper, because custom pieces mean you run the risk of failures while trying to work to a deadline."

To illustrate the complexities of glass making, Landa took me to visit Jan Frydrych, an internationally renowned glass artist who has produced pieces costing many thousands of euros for celebrities and statesmen such as Elton John and Bill Clinton. Frydrych works only with the highest quality optical glass and will often grind and polish to within tolerances of just five microns, equivalent to five-thousandths of a millimetre. The starkly perfect results resemble something that you might find on an alien spaceship. Frydrych was also working on an enormous chandelier for Crystal Caviar containing 160 individual pieces of cut glass. It takes the veteran glass worker a full day to shape and polish just four pieces.

Installing glass pieces aboard a moving yacht is, of course, very different from a stationary residence or hotel on dry land. To this end, Landa has set up his own test facility where glass lamp fixtures are left for up to a week on a vibrating frame to check that no hidden faults appear and various adhesives can be immersed in salt water to simulate a humid marine atmosphere. This is where his experience of working aboard large yachts has proved invaluable:

"When you combine two or three techniques you already have something different..."

"Where my background has come in useful is that I can make sure that custom pieces are adapted to the budget, designed for installation aboard a yacht and modified for fixing, which can't be said for ready-made pieces. It's all about staying one step ahead by thinking the project through from design to installation."

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JUSTIN RATCLIFFE

THE DESIGNER
REYMOND LANGTON

LAUNCHED IN 2006, 68-METRE *KISMET* DREW ON THE COMBINED REPUTATIONS OF ESPEN OEINO, REYMOND LANGTON (RLD) AND LÜRSSEN. THE INTERIOR DESIGN IS A SUBTLE MÉLANGE OF ART DECO AND THE OWNER'S PERSIAN HERITAGE AND IS NOTABLE FOR ITS INVENTIVE USE OF GLASS ARTWORKS THAT FORM A POWERFUL ARCHITECTURAL ELEMENT OF THE OVERALL DESIGN CONCEPT.

A PRIME EXAMPLE IS THE CURVED GLASS PANEL THAT SITS BEHIND THE SPA BATH IN THE MASTER BATHROOM. IT CREATES A STYLISH AND ARTISTIC DIVISION BETWEEN THE BATH AND WALK-IN SHOWER. TAKING INSPIRATION FROM ANCIENT PERSIAN AND EGYPTIAN INFLUENCES, THE CONCEPT OF A FAN OF PEACOCK FEATHERS EVOLVED. PASCALE REYMOND AND JASON MACAREE OF RLD, ALONG WITH INTERIOR SUPPLY, WHO REPRESENTED THE GLASS ARTISTS JULIA AND COLIN WEBSTER OF GLASSZOO (ALSO RESPONSIBLE FOR A SIMILAR PANEL WITH LEAF DESIGNS IN THE MAIN SALOON AND A GLASS SKYLIGHT SCULPTURE IN THE UPPER DECK LOUNGE), WORKED CLOSELY TOGETHER TO CREATE THIS CHALLENGING PIECE. AT FIRST GLANCE, YOU MAY WONDER WHAT COULD BE SO CHALLENGING, BUT THERE ARE A LOT MORE COMPLEXITIES AND TECHNICAL ACHIEVEMENTS IN THIS PIECE THAN FIRST MEET THE EYE.

WORKING WITH THE COMBINATION OF KILN-FORMED GLASS, INDIVIDUALLY HANDMADE GLASS STRINGERS, METAL LEAF, OPAQUE AND CLEAR GLASS COLOURS AS WELL AS DIFFERING GLASS TYPES, BECAME SOMETHING OF AN EXPERIMENT IN COMPATIBILITY. THE WHOLE THING COULD HAVE ENDED IN A RATHER LARGE MESS, UNLESS EXPERTLY CONTROLLED FROM THE OUTSET AND PAINSTAKINGLY MONITORED THROUGHOUT THE ENTIRE, NOT TO MENTION LENGTHY, TESTING, SAMPLING AND MANUFACTURING PROCESS.

"THE PRECISION REQUIRED TO ACHIEVE AN ABSOLUTE, EXACT RADIUS FOR THE CURVE GUARANTEEING A SEAMLESS JOIN BETWEEN ALL THREE PIECES WAS THE TRICKIEST OF ALL THE CHALLENGES," COMMENTED JULIA.

THE SCREEN CONSISTS OF THREE CURVED PANELS, EACH OF WHICH COMPRISE TWO LAYERS OF FUSED GLASS WHICH, WHEN KILN FIRED TOGETHER, ALL HAD TO SLUMP CONSISTENTLY ON A METAL FORMER IN ORDER TO ALLOW THE PATTERN ACROSS THE THREE PANELS TO MARRY. THE REQUEST FOR THREE-DIMENSIONAL BUBBLES TO ADD TEXTURE TO THE GLASS CHALLENGED GLASSZOO EVEN FURTHER. THE BUBBLES HAD TO BE OF A SUFFICIENT SIZE TO CREATE THE DESIRED EFFECT, BUT PREVENTED FROM BEING SO LARGE THAT THEY MADE THE GLASS TOO THIN AND FRAGILE TO THE TOUCH. JONATHAN FARRAR OF INTERIOR SUPPLY REMARKED THAT WHILST HE IS NOT ONE TO SHY AWAY FROM A CHALLENGE, INTERPRETING A LITERAL BRIEF AND BRINGING TO LIFE PASCALE'S VISION, AND THEN THE WHOLE MANUFACTURING, DELIVERY AND INSTALLATION PROCESS, WAS "SCARY AS HELL."

ONCE THE FRAGILE PANELS WERE ALL MADE PERFECTLY TO ORDER, THE CHALLENGES CONTINUED WHEN THEY HAD TO BE PACKED AND TRANSPORTED FROM ENGLAND TO GERMANY WHERE, UPON ARRIVAL, THEY WERE TO BE INSTALLED AT WHAT WAS A SOMEWHAT LATE STAGE IN THE YACHT'S PROGRAMME. THE MAJORITY OF THE BATHROOM WAS ALREADY IN PLACE, AND TO ENSURE A SNUG AND SECURE FIT THERE WAS ONLY A MINUTE TOLERANCE FOR ENSURING THE PANELS SAT PRECISELY WITHIN THE CHANNELS SET INTO THE BATH SURROUND, PILLARS AND CEILING DETAIL. EVERYONE HELD THEIR BREATH AS THE PANELS SLIPPED FLAWLESSLY INTO PLACE, FOLLOWED BY SIGHS OF RELIEF ALL ROUND.

AQUOS YACHTS

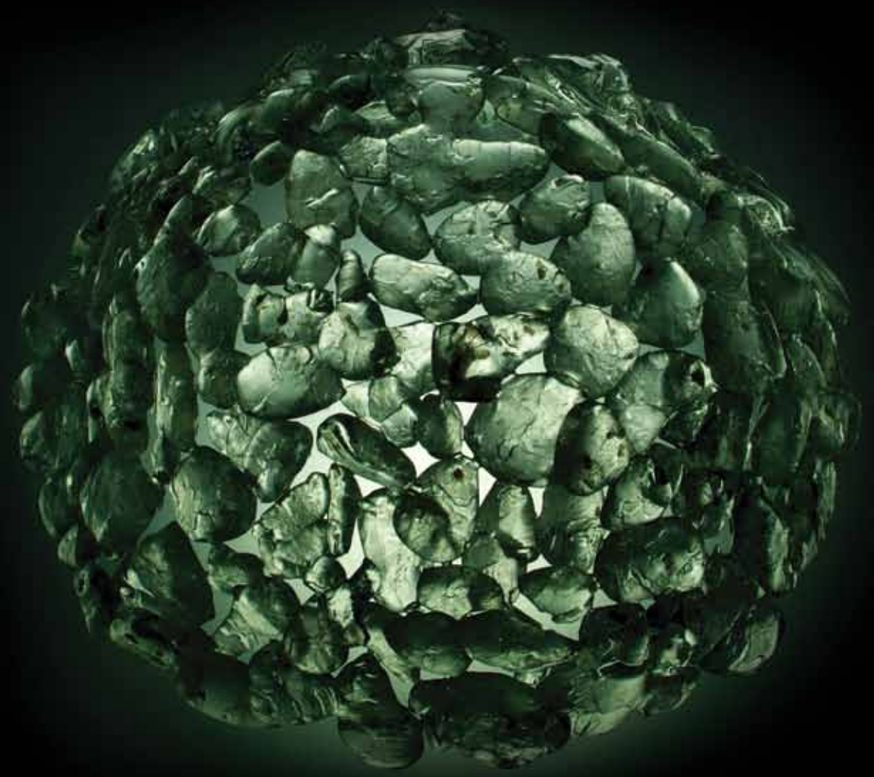
THE SUPPLIER
GLASSHAPE

FOUNDED IN 1986, GLASSHAPE LTD IS NEW ZEALAND'S LEADING ARCHITECTURAL AND AUTOMOTIVE GLASS BENDING AND PROCESSING COMPANY. THE COMPANY HAS FITTED ITS DURASHIELD MARINE GLASS TO SEVERAL RECENT YACHT PROJECTS, INCLUDING *BLISS* (YACHTING DEVELOPMENTS) AND *BIG FISH* (MCMULLEN & WING). CEO ANDREW FORREST DESCRIBES THE GLASS FITTING PROCESS ON THESE TWO PROJECTS.

DURASHIELD MARINE GLASS BROKE RECORDS WITH BOTH *BLISS* AND *BIG FISH*. THE FRONT WINDSCREEN OF *BLISS* WAS MEASURED IN AT 3300MM WIDE X 2000MM HIGH X 46MM THICK, MAKING IT THE LARGEST DURASHIELD WINDSCREEN EVER FITTED, WHILST *BIG FISH'S* SIDE WINDOWS ARE THE LARGEST WINDOWS MANUFACTURED FOR A SUPERYACHT IN AUSTRALASIA, MEASURING IN AT OVER 6M², WITH A WEIGHT OF 470KG.

AS ALWAYS, SUPPLYING GLASS ABOARD A SUPERYACHT BRINGS WITH IT THE CHALLENGES OF OFFERING THE ULTIMATE IN STRENGTH, CLARITY, NOISE REDUCTION AND SAFETY REGARDLESS OF CURVATURE AND THE THICKNESS OF GLASS. OUR TECHNICAL TEAM ASSESSED THE REQUIREMENTS OF EACH BUILD, PAYING SPECIAL ATTENTION TO THE GLAZING POSITION, OPTICAL QUALITIES ACHIEVABLE, WEIGHT-SAVINGS AND, OF COURSE, CLASS REQUIREMENTS. THE GLASS FITTED IN BOTH THE *BLISS* AND *BIG FISH* BUILDS WERE A COMBINATION OF HEAT-STRENGTHENED GLASS TO GAIN THE BEST OPTICS, LAMINATED WITH A SPECIAL POLY-ACRYLIC INTERLAYER DEVELOPED BY US, RESULTING IN AN OVERALL STRENGTH GAIN OF OVER 500 PER CENT. THE GLASS PANELS WERE THEN TESTED UP TO 25 TONS/M², AND WITNESSED BY THE CLASS SOCIETIES IN ACCORDANCE TO THEIR REQUIREMENTS. FOR EXAMPLE, THE FRONT WINDSCREEN OF *BLISS* HAD TO WITHSTAND A TEST PRESSURE OF 150 TONS FOR 15 MINUTES AND REMAIN INTACT.

FOR THE LARGER PROJECTS, OUR TECHNICIANS ALWAYS MAKE A SITE VISIT TO THE YARD AND ELECTRONICALLY MEASURE AND DIGITISE ALL THE WINDOWS, FLAT OR CURVED. THESE MEASUREMENTS ARE THEN TURNED INTO A 3D CAD FILE FOR THE YARD TO CONFIRM FOR MANUFACTURE. THIS SERVICE IS A HUGE HELP TO THE YARD, AS IT ELIMINATES HAVING TO MAKE FIBREGLASS TEMPLATES FOR WINDSCREEN MANUFACTURE. ALL THE WINDOWS ON *BIG FISH* WERE ALSO DIGITISED AND NOT A SINGLE PANEL HAD TO BE REMADE.



WHAT'S WHAT

01/COMMON GLASS
AN AMORPHOUS (NON-CRYSTALLINE) SOLID MATERIAL CONTAINING ABOUT 70% SILICON DIOXIDE (SILICA), WHICH IS THE SAME CHEMICAL COMPOUND FOUND IN QUARTZ, AND ITS POLYCRYSTALLINE FORM, SAND. IT BREAKS INTO SHARP PIECES, IS INERT OR BIOLOGICALLY INACTIVE, TRANSPARENT TO VISIBLE LIGHT AND 100% RECYCLABLE.

02/CRYSTAL
HIGH QUALITY GLASS THAT (ACCORDING TO EU DEFINITION) MUST HAVE A REFRACTIVE INDEX OF AT LEAST 1.520, MAKING IT SPARKLE, AND A DENSITY OF AT LEAST 2.45KG/L. LEAD CRYSTAL MUST CONTAIN LEAD OXIDE TO A LEVEL OF AT LEAST 10%. OTHER GLASS USED FOR STEMWARE CAN ALSO CONTAIN OXIDES OF POTASSIUM, ZINC OR BARIUM.

03/FLOAT GLASS
A SHEET OF GLASS MADE BY FLOATING MOLTEN GLASS ON A BED OF MOLTEN METAL, TYPICALLY TIN. THIS METHOD GIVES THE SHEET UNIFORM THICKNESS AND VERY FLAT SURFACES. MODERN WINDOWS ARE MADE FROM FLOAT GLASS. THE METHOD IS ALSO KNOWN AS THE 'PILKINGTON PROCESS', NAMED AFTER SIR ALASTAIR PILKINGTON WHO PIONEERED THE TECHNIQUE IN THE 1950S.

04/LAMINATED GLASS
A TYPE OF SAFETY GLASS THAT HOLDS TOGETHER WHEN SHATTERED. IN THE EVENT OF BREAKING, IT IS HELD IN PLACE BY A FILM OF POLYVINYL BUTYRAL (PVB) BETWEEN ITS TWO OR MORE LAYERS OF GLASS. PRODUCES A CHARACTERISTIC 'SPIDER WEB' CRACKING PATTERN WHEN THE IMPACT IS NOT ENOUGH TO COMPLETELY PIERCE THE GLASS.

05/LEAD GLASS
POTASSIUM SILICATE GLASS THAT HAS BEEN IMPREGNATED WITH LEAD OXIDE DURING FABRICATION. IN THE CASE OF STEMWARE AND DECORATIVE GLASS THE PURPOSE OF THE LEAD IS TWOFOLD: TO INCREASE THE REFRACTIVE INDEX OF THE GLASS AND THUS ITS LUSTRE OR SPARKLE, AND TO SOFTEN THE GLASS FOR DECORATION.

06/LOW EMISSIVITY (LOW-E) GLASS
LOW EMISSITIVITY IS A QUALITY OF A SURFACE THAT RADIATES, OR EMITS, LOW LEVELS OF RADIANT ENERGY. TO MAKE LOW-E GLASS, CERTAIN PROPERTIES SUCH AS THE IRON CONTENT MUST BE CONTROLLED. SOME TYPES OF GLASS HAVE NATURALLY LOW EMISSIVITY, SUCH AS BOROSILICATE OR PYREX. ALSO SPECIAL COATINGS BASED ON METALLIC OXIDES CAN BE APPLIED TO THE GLASS SURFACE.

07/TOUGHENED/TEMPERED GLASS
GLASS THAT HAS BEEN PROCESSED BY CONTROLLED THERMAL OR CHEMICAL TREATMENTS TO INCREASE ITS STRENGTH BY BALANCING INTERNAL STRESSES. IT WILL USUALLY SHATTER INTO SMALL FRAGMENTS INSTEAD OF SHARP SHARDS WHEN BROKEN. A COMPONENT OF BULLET-PROOF GLASS.

08/URANIUM GLASS
GLASS WHICH HAS HAD URANIUM, USUALLY IN OXIDE DIURANATE FORM, ADDED PRIOR TO MELTING. ONCE MADE INTO TABLEWARE AND HOUSEHOLD ITEMS, IT FELL OUT OF WIDE-SPREAD USE WHEN THE AVAILABILITY OF URANIUM DECLINED DURING THE COLD WAR. URANIUM GLASS IS ENJOYING A REVIVAL IN ART GLASSWARE AND IS CONSIDERED SAFE.