In the latest of his series of exclusive foci for *Asian Glass*, P.Carlo Ratto discusses how the techniques and issues faced previously in refractory manufacture should be heeded in order to push forward with future development.

Glass and refractories, more than in other industrial segments, have been strictly connected all along a story that evolved in about six millennia. Refractory materials were used, in fact, well before the very concept of materials resistant to high temperature, abrasion and chemical aggression was developed. With the advent of shaped glass, and particularly container glasses (bottles) developed pouring glass around sand molds more than three millennia ago and then through blowing technology about two millennia ago, it was necessary to have available a decent amount of molten glass and, of course, some kind of container with acceptable stability and resistance to alkaline corrosion at the glass fusion temperature.

While samples of ancient manufactured glass items have survived several tenth of centuries, we have little evidence of the old refractories used in their manufacture, since the very nature of these materials is that to be consumed and destroyed by the utilization process; we know that very likely quartzites and clays must have been the main raw materials, compatibly with the glass fusion temperatures that were surely much lower than in modern processes, the alkali content much higher, the forming process viscosity possibly higher and the level of smelting/fining generally incomplete.

So called refractories, empirically selected from naturally occurring materials, almost exclusively belonging to the Al₂O₃-SiO₂ range of composition have been utilized for millennia, but without developing any appreciable scientific understanding until modern times.

Glasses composition did only slowly evolve with the availability of better heating systems (wood to coal and later on to oil and gas), changes of alkali sources, higher fusion temperatures and better glass fining, but glass quality was still limited, beside the utilization of poor raw materials, by the nature and purity of the refractories in contact.

It seems amazing but, before observing a significant development of glass and refractory we must get to the industrial development of the 1800s and, before coming to a scientific understanding of the refractory very nature, we’ll have to wait for another century.

Within the 24h condensed historical perspective of glass and refractory materials, we are indeed talking about the very last few minutes!

During 1800s both the glass and refractory craftsmanship turns progressively to industry and basis are laid to make the major progresses that will eventually deploy in the twentieth century; it is in fact during 1800s that better combustion systems, larger and better furnaces (up to the continuous regenerative Siemens furnace), new raw materials (e.g. soda Solvay) became progressively available.
Twentieth century, in fact, was the period that generated and developed all the scientific and technologic basis for not only produce progressively evolved and specialized refractories, but also to create a huge amount of know-how around the working mechanisms of refractory bodies, the way they interact with the molten materials in contact and the way they spoil in the working environment.

**Milestones not millstones**

Some of the milestones in the refractory technology developed in the past age, of paramount importance for the glass segment, have been the “invention” of fused cast refractories around 1920 and the advent of isostatically pressed bodies around 1940 and the progressive application to larger blocks up to the size bodies around 1940 and the progressive application to larger blocks up to the size compatible for glass tank design. Also the range of different refractory chemistry has been greatly expanded, parallely to the improved understanding of natural and synthetic raw materials (periclase, chromite, chromag, corundum, zircon, zirconia, spinels, SiC, graphites and so forth). In the glass production, periclase, chromag, AZS have taken a great share in regenerators, while zircon, AZS, alumina, HZFC, isopressed eskolait, AZSCr, Al-Cr have been determining a real revolution in the glass furnaces performance (specific pull), durability (campaign life), efficiency (higher temperatures) and in the glass quality, through reduced cession of defects and improved fining, not to mention the economical aspects. As a most important feature of this booming, has been the explosive ramification of new and different types of glass, a lot of them serving the booming communication technologies (glass optical fibers, FPD devices of all kinds, new illumination systems...), but also in new areas like nuclear waste encapsulation, PV panels, safety and architectural components.

Beside this qualitative booming in glass range, the same has been necessarily happening for the refractory that not only supported but actually made it possible developing a pile of “new glasses”, most of them characterized by an exasperated demand of intrinsic glass quality. One bold example is the thin flat glass family for FPD, a chemically heterogeneous family of glasses mostly produced through two different processes technologies (modified float and “fusion” overfloat process), having in common an utmost glass quality demand and in most cases the utilization of electrical power as main or exclusive source of fusion energy.

While HZFC (High Zirconia Fused Cast) refractories are compatible with an extra-low defects cession, the same (in the initial design of these refractory specialty) have a major weak point in the low electrical resistivity, particularly when highly resistive aluminate glasses are being processed in all electrical smelters. As an answer to this issue, major refractorists have developed HR (high resistivity) versions of HZFC, with a compromise between increased electrical resistivity and other features of these special HR-HZFC bodies; to be noted that, as a consequence of variable glass chemistries and different smelting furnaces, a family of “tailor made” HR-HZFCs have been developed. To achieve these results, a deep understanding of the conductive mechanisms within the refractory structure and the way(s) to alter the same has been necessarily developed. Similar reasoning can apply to the development of the oxyfuel technological platform.

All in all, we can say that, in the twentieth century the explosion and qualitative ramification of glass types, supported by newly developed and optimized glass technologies, have been made possible by a parallel and synergic development of new and optimized, tailored refractories, the relevant technologies and scientific understanding.

The massive amount of know-how so produced has made it necessary to develop a generation of glass and refractory technologists, specialized for the glass problems and opportunities; as a matter of facts, and because this happened not only in the glass world, the profile of the generic refractorist has disappeared (except in certain academic environments!) and refractory specialists for glass have become a kind apart to the point that, today, experts of glass contact and superstructure are generally not the experts of refractory for regenerators packages, foretelling a further fragmentation in the specific expertise.

But this glowing picture of an exciting renaissance in the world of glass and refractories is far from what we see nowadays. Something weird happened in the last couples of decades of twentieth century and up to now.

**Financial pressures**

Starting in the last couple of decades of the 1900s, an unprecedented global financial (and then economical) crisis has longly hit western world bringing several regions to recession, reducing consumes and eventually hitting China role of the global productive hub. This well known picture overlapped the advent of low-cost refractories for glass (particularly fused-cast specialty) now made available
to the western world under a fragmented structure of providers and a complex commercial configuration.

This new and turbulent scenario has determined a strong pauperization in the chain between raw materials, glass and refractories and a very competitive environment where diffused overcapacity and struggle to reduce costing has been and still is the frame in which companies deploy specific survival strategies.

In the area of glass and refractory, as a matter of facts, the few remaining resources dedicated to research and development, have been diverted from innovation to cost reduction and search of the best compromise between savings and quality. In several cases, it was accepted the concept that, in the end, better compromising a little bit the quality of a surviving company than shutting doors of the best quality manufacturer.

The traditional concept that quality always pays, at least in the area of commodities (that represent the larger volume), is not corresponding to the actual truth; for what it is major western producers of fused cast, in most cases, they had to delocalize activities accepting a certain degree of quality compromise in exchange of the capability to survive the harsh environment.

With few low-volume exceptions (e.g. the FPD glasses and relevant HR-HZFC refractories), the major traditional sectors of glass & refractories (container, float) have mostly exhausted the strong development impulse of the first half of twentieth century and this will last until next economical global strong cycle.

All along this three decades of anguish a large amount of technical, scientific competent staff has been expelled out of corporate services in both glass and refractory industries, in the panting effort to reduce fixed costs and focusing in the financial/commercial aspects of the business. This well appreciable and understandable effort has clearly moved procurement focus away from technical/quality aspects and much closer to financial/economical aspects, meanwhile privileging short term advantages against long term, tactics against strategies.

This process has moved so far that, in many cases, companies are losing some critical piece of know-how requested for handling certain aspects of the business. Within the glass industry, I refer to the furnace engineering department, glass problems (often related to glass-refractory interaction) resolution, process improvements; within the refractory range, the capability to develop really new products and provide solutions supporting next wave of glass innovations.

To cover certain needs, companies are now resorting to technical consultants when strictly necessary and, curiously, a whole generation of technical consultants are owning and preserving a kernel of know-how in the area of glass and refractories that has been expelled from suffering industry together with a generation of technicians.

It may sound quizzical, but in this wave of dark decades, consultants are taking care of a know-how core as it was indeed in many monasteries in the European Middle Ages when information was handed down via classical culture, through the work of copying ancient works, with the difference that now this bunch of valuable professional knowledge is not going to be written in manuals and is waiting to be transferred to the next generation of technicians that, eventually, will be requested to support the next renaissance.

Training activities will be needed, in the short term future, to hand down knowledge before it gets lost. Since, eventually, it will be natural starting a new cycle; that day technical competence will again be considered a value, not anymore a mere cost aggravation.