EXPLORING THE FRONTIERS OF GLASS IN DESIGNED ENVIRONMENT ACROSS SCIENCE, TECHNOLOGY AND THE ARTS

Anthropology of Glass

The Journal of Architectural Glass Concepts

THE GLASS BEAD GAME IN MINERAL EXTRACTION

THE IMPACT OF LIGHTING

GLASS REEFS

ADOLPHE LACROIX

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Cover Photograph: Dr. Sally P. Leys  
TOC Photograph: Tyler Lake
Welcome to the latest edition of Architectural Glass Concepts. Volume 5 explores the theme of anthropology of glass by looking at the evolution of human interaction with glass, the reliance of modern society on glass, and its social and technological uses from past to present day in architecture related areas.
THE GLASS BEAD GAME IN MINERAL EXTRACTION

Benjamin Roggasch
Photography by Tyler Lake
Hermann Hesse’s futuristic novel The Glass Bead Game, published in Switzerland in 1943, revolves around a game played by people with a broad knowledge of many disciplines. The players make profound connections between what often seem like unrelated topics in both arts and sciences. These connections gradually become more and more interconnected and mutually relevant. Just like in The Glass Bead Game, recent advances in the game of mineral extraction have brought together many disciplines and areas of knowledge to revolutionize processes throughout the mining industry.

To prepare for our interview with Purity Systems Incorporated (PSI) and Professor Edward Rosenberg of the Department of Chemistry and Biochemistry at the University of Montana about their work on silica gel, it was necessary to study background information about recirculation of water in boilers, which provides some insights into mineral extraction by ion exchange. Boiler technologies use clay, zeolite, polyresin, lime and other minerals to keep the pH balance of boiler water stable, in order to maintain the metal integrity of pipes and to keep the “tiny critters” professionally known as Total Dissolved Solids (TDS) from accumulating in the water.

Boiler technology was a backbone of the industrial revolution. The process of running a boiler plant is relatively constant whether in a nuclear reactor, in a coal-fueled or a natural gas-fueled power plant. The main difference among these is that a heat exchanger separates nuclear boiler fluid from the steam that turns the generator. Another big difference is that for a nuclear plant backup power is vital for cooling the fuel, while for a large coal or natural gas power plant the backup generators are used to keep the massive turbines turning in the event of a shutdown, in order to ensure the shafts do not bend.

The “glass beads” -- or the silica gel -- that Professor Rosenberg has been developing can be used for analytical detection of minerals in a feed as well as the capture of most minerals by the ion exchange process with a glass resin. This is a revolutionary development for the mining industry, as well as for the environmental clean-up and restoration industries, recycling and mining rare earth minerals and it supports efforts such as remediation of environment, improving the efficiency of chemical separations processes used in the mining industry, or maybe it could be used in a nuclear fuel reprocessing facility for various chemical separations needed for that process.

PSI and Professor Rosenberg’s hard work has paid off with a remediation process for environmental damage of Acid Mine Drainage (AMD). Some of today’s largest environmental problems are a direct result of mining and the negligent approach to open pit mining. With PSI on the job, the open pit technique can still be used and any accumulated water can be purified and released back to the ecosystem, while collecting more minerals helps offset the costs. As the demand for clean water grows, silica gel will be on the forefront of water purification for many years to come.

When speaking with Dr. Bradley R. Johnson at PNNL (see AGC volume 5, issue 1, “Scientific Solutions to Nuclear Waste Environmental Challenges”), AGC enquired about the use of silica resin to treat nuclear waste by ion exchange. Dr. Johnson explained that ion exchangers are used to deal with cleaning up nuclear waste. For example, the sludge from the tanks at the Hanford nuclear facility will be processed to separate high level waste from low activity waste. Part of that process will use ion exchangers to separate radioactive cesium, among other elements. Ion exchangers are also used to purify and clean up the water being used to cool and manage the recovery of the damaged reactors at Fukushima. A glass-based resin bead system might be effective and usable in those systems.
THE DIFFERENCE BETWEEN BIOGENIC SILICA AND GLASS BEADS

The man-made glass beads for specific highly technical tasks (discussed in this article) are manufactured in spherical and irregular shapes, of porous silicon dioxide made synthetically from sodium silicate. Naturally occurring silica is mined for many uses, but is contaminated with trace amounts of other minerals, which makes it unsuitable for mineral extraction by ion exchange and lacks the required porosity. The synthetic glass beads are compositionally very similar to biogenic silica, as seen on the front cover of this issue and described in detail in the article "Glass Reefs". Biogenic silica is any silica made in a biological system, through entirely solution chemistry processes. The structures made of biogenic silica range from diatoms, a group of unicellular algae with the nano-scale porosity of their silicified cell walls, to the large glass sponge reefs that cover hundreds of square miles of the sea floor. Diatomaceous earth, which consists of the accumulated terrestrial deposits of diatom skeletal remains which were formed in ancient marine habitats, is an abundant natural resource used in a wide range of applications. Because of its small-scale porosity, diatomaceous earth is widely used as a filter medium for removing the fine particulates from beer. The complex architectural lattice of diatomaceous earth also makes it a mechanical insecticide: the sharp jagged structures absorb lipids from the insects’ exoskeletons, causing the insects to die of dehydration; the same effect works against slugs. It is also the stabilizing element in dynamite, mixed with nitroglycerin and rolled up tight to form the common mining explosive.
AGC: Hypothetically, can you engineer a single use silica resin absorbent for a variety of metals?

PSI: Yes, a single resin can be used for a variety of metals. We would also modify the feed to help target certain metals.

AGC: Can you do a single use or absorbent glass resin non ion exchange?

PSI: No, we would still be using the ion process, just not stripping it off. We could collect it and then dispose of it. This would be an ion capture instead of an ion exchange. Some things are harder to take back off the resin like cesium.

AGC: Some metals are more difficult to take back off the resin?

PSI: Yes. The markets we tend to supply are geared to collecting valuable metals out of a large feed rather than cleaning a feed. But, for a feed with cesium in it you just want to get rid of it and our materials work quite well for that.

AGC: PSI is currently capturing cesium?

PSI: Yes, one part of the technology is getting your metals to load on the resin and the other part is getting those metals back off the resin, collecting and reclaiming are two separate processes that need worked out for each client.

AGC: How do you strip off your glass resin when it’s loaded?

PSI: We use a very concentrated acid for removing the metals back off the beads. Then our clients most often precipitate them back out.

AGC: What is the measurement of acid or release agent compared to the load?

PSI: We usually measure by bed volume, so by rinsing or stripping we use so many bed volumes to strip the metal off the resin. That way everything transfers up from the lab size to industrial size by referring to a bed volume. The majority of your material comes off the column with the first bed volume of acid rinse and a second bed volume is really just to clean the resin a little more. A very low percentage of metal collection is from the second bed volume and it is often reused and sometimes topped off with a little fresh acid for its next rinse.

AGC: What is the percentage of acid to the mass of the silica gel for a rinse or to strip the column?

PSI: It’s volume to volume not mass to volume. Typically the amount of waste water we are processing is very dilute however above pollutant level allowance, so we will pump millions of gallons through your silica gel and then strip the column with just a couple of gallons of acid. Because the silica gel is just collecting the target items and letting clean water back out so you are shrinking the volume of your waste.

AGC: So it’s a pretty minimal amount of release agent compared to the bed volume?

PSI: Yes, comparatively.
AGC: How well do PNNL glass beads work for capturing minerals for direct to vitrification processes?

Professor Rosenberg:
PNNL resin has more uniform pore sizes and the pore sizes are very small. For our applications it’s not very useful. Their resin is harder to strip and the kinetics of the matrix is less efficient and slower; and for vitrifying metals that are bound to a material I thought our silica resin would be better. The difference is their vitrification process and the porous ordered phases of silica developed at PNNL by Dr. Glen Fryxell, a very good scientist whom I really respect.

AGC: Is all the resin made in China?

Professor Rosenberg:
Right now the manufacturing is in China; however, we are bringing it to the US.

AGC: Is it because of the machinery required to do it?

Professor Rosenberg:
Not really, the raw materials are cheaper there and the initial markets were in Australia and China so it made sense. Hopefully we will be able to break market elsewhere in the world. So we are looking forward to having manufacturing done here.

AGC: It seems like your material would be perfect for one time use for vitrification purposes.

Professor Rosenberg:
I have been working with the transuranium elements, particularly thorium and uranium, and we have a material that absorbs these quite efficiently. There is some selectivity, but it co-loads iron in the high oxidation state. For this purpose that you’re talking about I don’t think it is a disadvantage. Because, if you’re right about what you are saying, the transuranium elements are presently at very low concentration in run-off from nuclear reactors. I am actually getting a visitor here from South Africa, a professor from the University of South Africa who we have been collaborating with, and over there the uranium is in gold mine tailings. He gave me the makeup of the soluble tailings. We did some work on the material that is leaching out on to the surface waters and we were able to pull out the uranium quite effectively. It co-loaded the iron but passed most of the innocuous metals, sodium, calcium, magnesium and so on. The key test to do would be to see how well this would work in very low concentrations of uranium, somewhere in the order of 10 to 100 parts per million.

AGC: Are you able to manipulate the shape of the pores on the silica gel?

Professor Rosenberg:
The materials that we use that are being manufactured are amorphic silica gels. We specify a minimum pore size, but these particular silica gels have a huge range of pore sizes. This is both an advantage and disadvantage. We use a technique that is not different from what Dr. Fryxell did. Using what is called sol-gel technology, we were able to narrow up the pore sizes and make them much more uniform. So we can do that using this alternative approach. Whether that is commercially competitive remains to be seen, although I am optimistic. We found that depending on what kinds of metals you
wanted to capture the narrow pore size was good or not as good. So with the amorphous silica we could put any kind of modifier on there and it would work, especially using some of the chemistry that we have developed at the University of Montana. With the sol-gel material we have developed that has a much narrower pore size distribution we were not able to place the bigger molecules that we wanted to, they did not fit. The silica gel material that we developed is as robust if not more than the amorphous gel.

What we do is take the amorphous silica gel and put a polymer on it; the polymer has groups that are easy to modify chemically. Then you put small molecules on the polymer that make it selective for a different group of metals or a particular metal.

AGC: What does amorphous mean?

Professor Rosenberg:
Amorphous means non-crystalline and unordered. So, the shape of the particle is the macro structure. But that’s more related to how they are mechanically developed. Amorphous means that there is no pattern to the pores. The gel made at PNNL is order phase. It’s kind of crystalline.

AGC: Do you use the glass beads for platinum extraction?

Professor Rosenberg:
Yes, that is one of our big low-hanging fruits. We have a commercial project going now in China and more coming online soon. It uses the first product that I have developed. We tested it with palladium and platinum, and it’s remarkable how well it works at low pH or high acidity. It pulls out palladium and platinum and passes all the base metals. Now this is very important because where you find palladium and platinum there are also high levels of base metals. Nickel, copper and cobalt are all valuables, but this product will pass all of those at low pH and will also capture those at high pH. The precious metal mining industry is one of our most promising markets.

AGC: Montana being one of the largest mining developments around palladium and platinum, they must be knocking at your door?

Professor Rosenberg:
We did work with Stillwater. Stillwater is the only operational platinum mine in the U.S. It’s actually a palladium mine. Most mines have more platinum than palladium, so this is the opposite. Again like with PNNL, they have a very well developed hydrometallurgical process, so they are not about to build a whole new plant and tear that down to make room for our process, which is the whole lot cheaper and simpler and has a much smaller footprint. We did a project that took the analytical laboratory waste and treated it. They never went anywhere with it. It’s very difficult to crack into an industry that has been doing the same thing for decades and decades. But like I said we are making inroads into that market right now.

AGC: Has the precious metal industry approached the University of Montana?

Professor Rosenberg:
They approached PSI and I have also been approached by some metal industry companies recently; we are working together on a lot of projects recovering platinum and palladium metals from spent petroleum catalyst.

AGC: Hypothetically, can you engineer a single use silica resin absorbent for a variety of metals?
Professor Rosenberg:
Yes, we have a range. The ones that are commercially developed are about five or six different ones and they each have different selectivities for different metals. We make other ones, but they have not been manufactured on a large scale.

AGC: Hypothetically, can you regenerate your silica beads with a minimal amount of release agent when extracting nuclear waste?

Professor Rosenberg:
In order for the silica gel to be commercially viable in terms of mineral processing or even remediation, you have to have a concentrating factor, so that when you load the material and strip it, it has to be more concentrated, otherwise you haven’t gained anything in terms of recovering the metal or even disposing of it. So yes, that’s the key and often a problem -- sometimes you can load something and it won’t strip. For the vitrification process that’s perfect, but for other processes you want it to strip and you want it to strip with the minimal amount of acid.

AGC: Even if you are doing nuclear waste you want the potential to keep reusing the same beads, especially if they are expensive.

Professor Rosenberg:
I know our stuff is a lot cheaper than what they are using at PNNL, the last time I looked at it.

AGC: If you were doing a multi-rinse cycle strips of loaded resin with hot particles that release agent, acid would start getting contaminated with radioactive particles. It seems much easier to keep loading clean material instead of dealing with it, but hypothetically is it possible to strip out hot particles/ uranium and then reuse the acid?

Professor Rosenberg:
Yes, we did that with uranium, but most uranium is not radioactive and I don’t have a license to deal with radioactive materials so we buy uranium that has been depleted from its radioactive elements, but it’s the same chemistry.

AGC: In the case of AREVA, the French nuclear clean-up company that uses chemicals to dropout or flocculate most nuclear waste out from water before release, could you use a glass resin to clean up what AREVA releases back to the Atlantic Ocean?

Professor Rosenberg:
It really depends on the concentration. The problem with radioactive materials is that some of them are very dangerous at very low levels, and one of the features of our material is that we can remove metals at very low levels. So I would have to know the details of what they are throwing into the Atlantic first before I would venture and say we could do that.

AGC: But you can do multiple stages. Let’s say you were looking at ten to twelve different minerals to extract and collect them; you could either load up multiple tanks or fill a tank with applicable beads, so in one tank we could hit all of the targeted metals, like a giant filter.

Professor Rosenberg:
You can have a column stacked with different resins all together; they are mixable because they don’t expand and contract and they are reusable, and that is not true with some of the other materials out there.

We did a project in Australia where they had contaminated ground water and I had, like you said, a variety of different metals in there and we took them all out. It won’t take out sodium, it does not work like a typical water softener; at high pH it will take out the calcium and magnesium and at middle to low level pH it will pass those minerals and will be selective for transition metals and the rare earth minerals and the actinides.

AGC: How are water softeners similar to ion exchange mineral extraction?

Professor Rosenberg:
Water softeners are ion exchange materials, but they are ion exchange compared to ion capture. So a lot of materials will take out the metal and put protons in there, and some of them will just take out the metal. Water softeners take out calcium and put
in sodium. The same companies that make water softeners make materials like ours and they call them chelator resins. They work the same as ours and there are competition and for certain applications ours are better; their products are cheaper so for certain applications theirs are preferred.

**AGC:** Are they using silica?

**Professor Rosenberg:** No, not at all, they are using polystyrene. You can’t use those for the actinides or the transuranium elements. They have had a lot of problems with that at the national labs using polystyrene resins because the radioactive particles they are emitting decompose the plastic. Our resin has a much larger cross section for capturing and reacting with those, because it’s silica, not plastic.
AGC: Is there a glass forming shop on campus?

Professor Rosenberg:
No. I used to blow glass and I made a lot of the equipment you see here.

AGC: A lot of people do not realize there’s a lot of glass involved in ion capture and exchange. When you look at small precious metal extraction kits, they are all glass and they need to be so you can see the reaction. So when you scale up the columns what kind of material can they be made of?

Professor Rosenberg:
We use glass in the lab, but on the bigger scale they use stainless steel. Sometimes they use polycarbonates. It depends on the back pressures and what acids are being used.

AGC: Glass is the shop size.

Professor Rosenberg:
Yes, you would not use glass on a full-scale operation.

AGC: If you were to attack the nuclear sludge, you’d run it through a course of sand first, before any of these silica beads, I imagine.

Professor Rosenberg:
This is an important point. In order for us to be effective it has to be dissolved metal ions. We don’t deal with colloidal or suspended particles. That’s not our game. In fact, one of the problems we have is that people buy our stuff, they don’t filter the feed coming in, and it ends up clogging the material, in some cases degrading it. I wouldn’t say it’s a disadvantage; I would just say it limits the scope of our application. So what they normally do is exactly what you said – they run it through a pre-filter and take out the suspended solids, and then all the material goes through.

AGC: That sounds perfect for AREVA. They should be buying this and treating their release water.

Professor Rosenberg:
I do not know why PNNL are not using it. I went to them and said, look, I got this product; and they said, “Oh, very interesting”, and I never heard from them again. Same story with the Department of
Environmental Quality of Montana. We had several meetings with them and never heard back from them. Never heard back from the EPA of the State of Montana either.

**AGC:** Could you clean up the Berkeley Pit with this?

Professor Rosenberg:
I did Berkeley Pit. I wrote a publication on it. We took a sample of the water right out of the pit, and treated it. The copper was 97% pure. We pulled out the zinc at 99% pure and magnesium was 83% pure. What I was looking at is a way of offsetting the cost of the remediation by making these valuable metal salts, but there’s not enough of this stuff in the Berkeley Pit to make it profitable by itself. But it would be a useful way to offset the price of remediation.

I do not know what to say, I am puzzled. Am I missing something here? Since then I have come a lot further along.

**AGC:** Sounds like a case of gross negligence.

Professor Rosenberg:
I have been funded before by the Department of Energy on other chemistry projects.

**AGC:** You would need to have glass for working on your current projects, right?

Professor Rosenberg:
Yes, in the devices for sure. Another interesting fact is that when you mount these metal complexes on silica resin, it changes the light emitting qualities and situates them to be more favorable to doing catalytic reactions and make them more favorable for doing metal sensing. This is what the National Science Foundation currently funds me for. Most of my group is working on new applications of these glass particles where we catalyzed chemical reactions, like, for example, putting a metal on the material binding it firmly and then using that as a chemical transformation.

These materials go beyond mining and mineral remediation. They are very good matrixes for making materials that promote chemical reactions.
ABSTRACT:

The structure and properties of inorganic-organic hybrid materials made from micro-particles of amorphous silica gel (150 – 500 microns) and silica nano-particles (10-20 nm) modified with aminopropyltrimethoxysilane (APTMS), poly(allylamine) (PAA) or poly(ethyleneimine) (PEI) have been studied. The APTMS nano-hybrids showed batch capacities for copper equal to or better than the corresponding micro-hybrids. The nano-particles showed very high loading of chloropropyltrimethoxysilane (CPTMS) and with mixtures of CPTMS and methyltrimethoxysilane (MTMS) but on modification with either PAA or PEI only a fraction of the chlorides were utilized, whereas the micro-particles reacted with related chloropropyltrichlorosilane (CPTCS) or with mixtures of CPTCS methyltrichlorosilane (MTCS) utilized >80 % of the loaded chlorides. For both the micro- and nano-particle hybrids the amount of polymer loaded was observed to be insensitive to the molecular weight of the polymer used. All of the amine-modified materials were catalysts for the Knoevenagel reaction but interestingly the micro-particles modified with APTMS were better catalysts than the corresponding nano-particles. Both the nano- and micro-polymer hybrids showed increasing copper capacities when made with 7.5:1 mixtures of CPTMS and MTMS or CPTCS and MTCS. Under acidic or basic conditions the APTMS nano-particles underwent hydrolysis and this was not the case for the corresponding micro particles or the polymer-modified nano-particles. These similarities and differences are discussed in terms of the density of hydroxyl sites and in terms of the role of the polymer in protecting the silica surface.
Transition metal complexes immobilized on silica-polyamine composites: micro- versus nano-matrices

International workshop:
Polymer Materials for Environmental and Forensic Application
Universidad de Concepcion
January 14-15, 2013

Department of Chemistry, University of Montana
Missoula, MT

Where is Missoula, Montana?
376,980 km² 935,670 people, 2.3 people/km² - more cows and sheep than people; Chile: 756,096 km², 21.3 people/km²; Italy: 295,000 km², 200 people/km²
Measuring the luminescence of the particles required a novel approach.

The particles were placed on black two-sided sticky tape used for SEM after putting the tape on a glass slide. The angle with the incident beam was adjusted to give maximum luminescence intensity.
Conclusions

• The large increases in excited state lifetime of the surface bound complexes can attributed to a combination of molecular volume, surface structure and the number of tethers to the surface.

• The luminescent complexes show similar chemical reactivity on SPC to that observed in solution.

• The SPC formulation can be successfully taken to the nano-scale. Independent of MW of PEI.

• The silica nano-particles have a much higher density of surface OH groups so that APTMS provides the same or more amine sites than the polymer but many are not utilized in metal binding.

• The Nano-particles are more sensitive to hydrolysis and the polymer provides protection against loss of surface functionality.

• The polyamine is clearly necessary to to stabilize the nano-surface sufficiently to survive the conditions of metal complex immobilization.

• Amine catalysis (Knoevenagel reaction) is best with the less encumbered aminopropyl group than with the polyamines. Micro better than nano.
REFERENCES

Polystyrene based ion exchangers in operating nuclear power plants keep the water pure and help control water chemistry. Control of water chemistry is very critical for two reasons: 1) to prevent corrosion, which leads to system failures, and 2) to prevent fouling – crud building up on the steam generators decreases performance and leads to more corrosion.

Using this technique, it is possible to control water chemistry to amazing purity levels: parts per billion (ppb), a precision comparable to a single raisin in a 100-ton load. Some of the primary elements of concern are chlorine, sodium, sulfur, and lead. A pressurized-water reactor has two separate water loops: one to cool the reactor and another to make steam. Technicians carefully control the water chemistry for both water loops.

Silica (SiO2) is also a contaminant of concern; in reactors, the concentration is kept below 10 ppb. In the primary loop, silica causes a problem in the steam generators because it will react with other contaminants such as aluminum and zinc ions to form complex oxides that will plate out onto the heat exchanger tubes and interfere with heat transfer. It can also form a scale coating on the metal. This is a problem for both primary and secondary water.

Common glass is primarily made of SiO2. If you are trying to control silica to less than 10 ppb, a glass-based ion exchange would not leach silica at neutral and acidic pH; at higher pH contamination of silica would be a problem. Operating a boiler at very high level pH would not likely slip by the operator and having another filter for silica could be an option. This approach to boiler control of total dissolved solids in water with silica beads would have several advantages over conventional approaches with polystyrene beads, the glass-based composites made by PSI are much less prone to damage by radiation than the more common polystyrene ion exchange resins used in ion exchange applications, which heat up and can even explode. Silica resin is usable for a multitude of applications surrounding the capture and exchange of almost all minerals and can do so in a single column that has no expansion compared to the plastic beads that expand and need multiple columns when dealing with multiple mineral captures. Another benefit is that you can extract your minerals with a glass bead over and over for thousands of cycles without much in the way of chemicals being used or if you wanted to vitrify your load due to higher level of radioactive waste you could do so without the plastic being in the way, a direct to vitrify is an option with PSI resin.

The water in a boiler system only lasts so long before it is all replaced, whereby a glass resin offers the ability to clean the water of total dissolved solids without the use of chemicals in a flocculation process for separation and you could then release the cleaned water right back to the environment without polluting or from all the creation of nasty chemicals currently being used by the industry. This approach to using the mining industry technologies goes far beyond nuclear power plants and has vast applications for an array of different problems that plague our civilization.
Bill: Feed water for all present-day commercial boilers/reactors is tested every hour for chemical additives and hardness, among other things. More comprehensive tests occur at longer intervals. Water is the lifeblood of many industrial processes. For example, the Lockheed SR-71 Blackbird was built mostly of titanium. Parts machined in winter were fine, but parts made in summer were brittle and broke due to summer water having more chlorine added. This gives an idea of how critical water can be, and this was only cooling water for machining. In closed boiler/reactor systems it is even more critical to maintain the correct water properties.
On a commercial boiler the water is tested every hour; the make up water and the condensate return are being tested all the time and make up water is produced to compensate for blow down being dumped. When blow down is being done, every chemical added to that make up water to make it non-corrosive and to maintain the pH balance in relation to the TDS and conductivity is also being dumped. That’s where little glass beads or any type of resin, whether silica based or another medium, are used; it’s all basically site specific. We have the capabilities to do this type of blow down polishing system now with Rosenberg’s and others research because they are able to pull the metallic ions out of solution, so we have the ability to clean up the condensate and blow down water without the use of the chemical flocculation process to separate minerals in water and capture them.
Ben: So water is a critical manufacturing resource?

Bill: Yes, water is basically used for everything you have in your hand or your house. You look around: there is drinking water, which is minimally treated, and then there is industrial water; we make a lot of industrial water because a 450,000 lb boiler taking roughly 60,000 gallons an hour rolls around in a steam circle. Basically, water is doing the work of what a tool and die makers use to do. Now look at the automotive industry: they hydro-form, and hydro-press car parts. All the paint we use is water based and you have mass quantities of water being used for making steel and all the baths with chemical soups that your cars get dipped in. Water has basically taken over what petroleum was doing earlier, as a carrier.

Ben: The ironic part of this is that water is the worst possible thing you could have in a glass manufacturing plant, compared to most industries.

Bill: In a glass manufacturing plant the last thing you want there is water. If you added water anywhere in that process you would seize up the machinery, destroy the product and everything else; you would have to rebuild everything if water got in there. Once you start up a glass machine, it will run about 12 to 13 years on one campaign; some of these machines are 100 years old and they have been rebuilt continually. Once they start it up they don’t shut it down unless something breaks.

Ben: So the low level waste collection of radioactive particles seems to be a perfect match for Rosenberg’s beads.

Bill: We have the ability to take the particulate out of the water and keep reusing the stuff, but at a certain point we still have to get rid of it; we know we can take out all the minerals. Have we created a resin that is capable of pulling a chemical? That’s where the AREAVA processes are using chemicals to basically drop the particles out of solution into a sludge base. They are not captured, however, because once you got a sludge you got to work that sludge, or whatever was created in a pond or a settling chamber; it’s going to have to be taken care of, one way or another. That seems to be adding a lot of processes where glass beads can actually absorb it all, in a single pass or with multiple matrix resins and do the same thing all the chemicals are doing.

Ben: Right, so what’s happening is that the mining industries have now succeeded the chemical companies.

Bill: Right. A standard old poly resin can handle a lot, but you are not going to be able to vitrify it because it will burn. Now when we blew up boiler number 4 in the mill, I had been asking for four years where all the zeolite was going and a year before the boiler blew up, we pulled the hand holds out of the bottom of the boiler; there are little tiny doors you can look into the tube systems and we pulled out 7 or 8 drums of zeolite.
Ben: What exactly is the composition of zeolite resin?

Bill: It would be styrene based. Zeolite resin is based off of what zeolite clay can do. It's a plastic that has been modified with roughly a hundred thousand holes on a bead and acts as a porous material. The zeolite resin used to come in 300 lb. cardboard drums with a plastic bag and it was damp, sealed and dated to when it was manufactured; it had to be used before so and so time, otherwise it had to be disposed of.

If the silica-based resin is used to get rid of radioactive waste, it's only going to be a single pass, because the moment you throw acid in you have got another medium that you have to take care of, so a single pass is the only way you can truly be on a clean-up sense of the low level nuclear waste in the water; you have the ability to pull out all of the heavy metals and you want to vitrify that and get rid of it. You want the water as clean as possible and dump it back in the stream, but keep all the waste on the glass beads and vitrify that, because if you turn around and use acid to shed it, then you got to figure out what to do with that acid. It would be a single pass if you were doing an actinide clean-up in the simplest way.

Ben: There seems to be a lot of different type of resins. There are glass resins, there is zeolite, aluminum.

Bill: Right, so you turn around and you see everything we created for the last 30 years and how we changed our processes. There is really no excuse for some of the things we are doing when we have the true ability to clean the stuff up again, especially in the case of a reactor where, if you are using chemicals to get rid of the TDS, you are still going to have to get rid of the chemicals and everything else used.

Ben: Do the spent fuel pools have to be clean too?

Bill: You bet, water that's in the cooling tanks is in essence feed water; it's got to be clean, or else it will start coating the fuel rods. That water is always being circulated and cooling something off; if the spent fuel dried out, it could start to burn up... it's hot!

Ben: How long does it take to cool down?

Bill: Five years or so.

Ben: After it cools down, can the spent fuel be vitrified?

Bill: Yes, that’s when they pull the pellets out of the rods and change them.

Ben: And the old ones can go to vitrification?

Bill: Yes, or that’s where you go back to chemicals and reprocessing.
Ben: How big are the pellets?

Bill: The little pellets are small, about 3/8” in diameter and less than an inch and a half long and there are long rods around 10 to 11 feet.

Ben: When the fuel is depleted and you’re not going to reprocess and want to get rid of it, that’s the vitrification part or, as I like to say, returning it back to ore, a stable glass ore of minerals.

Bill: Long term storage.

Ben: In this case I propose an idea for ship vitrification plants, a ship that could process contaminated water and have vitrification capabilities in small quantities with small containers. There can be different ships for low level waste, medium waste, and highly contaminated waste and different types of mineral clean-up capabilities.

Bill: Right.

Ben: This way vitrification would be done in smaller facilities.

Bill: That’s part of the name of the game there; the smaller you are the more you can do in reality. Making everything gigantic is fine but you still got to be able to move it around and there are more things that can be done with smaller things.

Ben: There is also National Research Council (NRC) information about boring under the ocean for storage.
Bill: Yes, but we have done a lot of that over the years. There are quite a few reactors, submarines and a lot of containers down there already.

Ben: Could you vitrify the spent fuel pellets?

Bill: You could, yes.

Ben: That’s what I was thinking: vitrify them inside of a ceramic jar that has a lid with an opening on top; fill it with glass to push all the air out, encase it in a box of lead and drop it into a molten glass sphere mold.

Bill: Did you look into the outfit in Sweden where they are digging a repository?

Ben: Yes, I think they have been doing it for seven or eight years now.

Bill: That’s the other way of looking at it. You take the dismantling costs: when time comes to dismantle these outfits, you start to understand they were really never built to be dismantled. That’s where you see that everything else you can reuse in a normal mill, whether it be a power plant, lumber mill or whatever, all that material can be reused, whereas with a nuclear plant you basically have a problem that nobody is going to want.

Ben: Why is geo-thermal a bit of an issue?

Bill: You cannot take things out of steam that are already made. I don’t know how they are doing it but I am guessing they are using acid cleaning in the heat exchangers and using multiple heat exchangers so they can get rid of the scale. I think the geoplant in California went broke and was bought out by another company. I believe it’s Greenland that’s got all the geothermal; they pretty much run off that, but how they are doing that I do not know. When you turn it around and use standard old boiler water, it’s strictly a chemistry game: you are just doing a balancing act and maintaining everything so it doesn’t self-destruct. Looking back into steam locomotives is where water treatment became a necessity, as all water is not equal in its make-up. The high mountain water directly from a glacier, such as Lake Huánuco in Peru, is the drinking water that is softer than what the standard household softener will ever discharge, but after it has made it into the rivers it has a lot of total dissolved solids. Going into most desert areas, the surface water is almost undrinkable without treatment. So, needless to say, the trains had big problems with feed water fouling boilers. We have come a long way in the treatment of processed water in that we have equipment that has 20/30-year lifespan. This is where Professor Rosenberg’s interview is most compelling, as we have been using zeolite resin bed systems for years, but they were not capable of the processes to capture metals. This is why boilers needed to be primed/blown down on a continued
basis, but with the work of Rosenberg and others there are now blow down reclaiming systems capable of removing the build-up of the dissolved metals in the blow down water. That was not the intended deed for this type of research as in the beginning the intention was to make mine clean-up profitable.

Ben: You think you could light the whole country off Yellowstone if it was a geothermal site?

Bill: You might be able to.

Ben: How many people does it take to run a nuclear reactor?

Bill: You look at the parking lot outside of the nuclear plants and you can see the number of people that are required to run one of them – we didn’t even have that many people in the pulp mill when we were producing 25 hundred ton a day; there was a minimal amount of people, but when you start looking at a nuclear plant, it’s kind of a self-perpetrated type of job. When you think of the water chemistry alone, he’s not just a water tender anymore, he’s got to be a full-fledged chemist. The whole nuclear reactor was sold as producing power cheaper than you could actually charge for because it was supposed to be so efficient. Well, it’s kind of a balancing act of keeping it from going critical, and all of this technology is fifties and forties technology and we’re still running it. Any steam boiler built in the last ten years has far more up-to-date instrumentation. When you have a system with a known loss built into it you got a problem. Then you turn around and you can’t be over a certain age to get in and actually be an operator and be trained because then you won’t follow the regime; you will ask questions. If they run those power plants anything like a pulp mill or a steel mill or anything else, you’ll run it to the ground, which is what they are doing when they are adding another twenty years to their life when it actually had a twenty to thirty year life span in the beginning. Now they are adding twenty years to these licenses, and they’re going to bring them into forty to sixty years of operation; they were never designed to do that. Radiation starts to make steel brittle and it does strange things to it.

Ben: Did you hear about Bed, Bath and Beyond pulling radioactive metal tissue boxes off the shelves due to getting tainted metal with radioactivity in it?

Bill: Yes, even worse than perhaps medical radiological waste in the tissue boxes is the nuclear industry wanting to recycle the old reactor steel. Well, we got about ten reactors sitting around with moderately hot steel and they are wanting to recycle it into the clean stream of metal to help offset some of the dismantling costs. That’s like shooting yourself in the foot. To say that it’s not going to hurt someone is a complete crock and a lie.

To see all this contamination coming off of Japan and see it make the Geiger counter jump around in Seattle, especially in the rain, is very concerning. The count should not be moving around much at all in Seattle; my counter would be going along at .05 and then all of a sudden it would spike up to .54 and then .35
microsieverts, and then all of a sudden jump up to .78 to .80 during rain, on the water which acts as a moderator. The only time I ran across that type of a number is when I was going along the desert by the Nevada test site, and that meter would go into red and danger.

**Ben:** This type of radiation exposure where you are ingesting a low dose over a long period of time, actually like right here in Seattle or in Hawaii, can be quite damaging.

**Bill:** Fukushima is affecting the whole Pacific Ocean. There is really no safe dose of radiation.

**Ben:** I saw a great documentary produced in Germany called “Nightmare Nuclear Waste.” This film goes into details of dumping of waste in the ocean, waste storage explosions, heavily contaminated sites and the complete nuclear cycle, via AREVA and Russia, which uncovers significantly more waste from the reprocessing of nuclear fuel than stated on AREVA’s charts.

Do we need the power that’s generated by nuclear reactors in the USA? It seems like a lot of risk for a sliver of the overall electricity generated in the world.

Thank you, Bill, for sharing your insight with AGC. This conversation leaves us with a lot of questions, but also – and more importantly – with possible answers and solutions, which our magazine may revisit in the future.
HELPFUL RESOURCES:

JOM; Materials Issues in Nuclear Waste Management:
http://www.tms.org/pubs/journals/JOM/0009/Yim-0009.html

PSR; Nuclear Power and France:

UNESCO - EOLSS; Nuclear Waste Management And The Nuclear Fuel Cycle:
http://www.eolss.net/ebooks/Sample%20Chapters/C06/E6-104-11.pdf

Truth-out.org; Seventy Years of Nuclear Fusion, Thousands of Centuries of Nuclear Waste:

New York State, Department of Health:
http://www.health.ny.gov/press/releases/2012/2012-01-12_contaminated_bbb_tissue HOLDERS_removed.htm

DOE; Radiation Protection Of The Public And The Environment pdf:

DOE; Recycling of Scrap Metals Originating From Radiological Areas:

Nightmare Nuclear Waste: https://www.youtube.com/watch?v=rk5ai0gOQHU&feature=player_embedded#

A Theory of Fukushima: http://www.youtube.com/watch?v=8l947Cw0fsY
The Fukushima Nuclear Crisis: Separating Fact From Fiction: http://www.youtube.com/watch?v=sAM85y8lFm4