Building the world's first sustainable magnet metal supply chain
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As a demonstration of the power of modern rare earth element (RE) magnets, the speaker brought a 2cm wide button shaped Nd/Pr/B/Fe magnet which weighed 25g which can lift 25kg i.e. a hundred times its own mass. His professional background is a mining engineer from Imperial College, beginning his career at Mt Isa in Queensland, followed by a stint in a gold mine in northern China near the border with Russia, where the winter temperature dropped to -50C. After that chilling experience, he moved to an Australian mine where the summer temperature reached +50C!

More recently he was looking for a new challenge, and came across an interesting project in Angola which had been spoken of as a copper deposit but was in fact one of several carbonatite intrusions in the Huambo province. After contacting the owners, he highlighted the significance of the deposit for the rare earth metals (RE) for the energy transition and in particular for magnets in wind turbines. The prospect was drilled and data was highly promising; at which point it is all too common for owners to sell it to the Chinese because they have the processing technology. Instead, the decision was made to attempt to go 'downstream' into separation for the individual metals, despite the fact that it is incredibly difficult irrespective of whether the initial mine-based processing is aimed at producing a carbonate or a sulphate, and that the carbonatite is rich in U & Th which therefore requires an additional ion exchange process to remove and store the radionuclides.

The main RE minerals in carbonatites are bastnasite $(Ce,La)CO_3F$ or $(Y,Ce)CO_3F$) and monazite (basically cerium phosphate: $(Ce,La,Nd,Th)(PO_4,SiO_4)$, but RE can also be recovered from weathered surface deposits known as ionic clays. In some cases, the carbonates are retained for separation while the phosphates can be used as agricultural fertiliser. The key aim is to do as much processing as possible at the mine, leaving a cleansed product to be shipped for final processing.

The RE elements have almost identical ionic radii and consequent very similar chemical behaviour, so the separation process for Pr and Nd is lengthy with about 27 stages of wet chemistry. Rocky Smith (ex-Mountain Pass mine in California) is the Pensana expert on this process.

At present virtually the only place in the world that undertakes RE separation is China (with the recent exception of Australian company Lynas which does its separation in Malaysia). So, the big question is if this nexus could be broken and, more particularly, if this could be done in the UK, which has a very proud record of chemical engineering and dedicated 'chemical parks'.

One of these industrial parks is at Saltend, on the Humber estuary and after getting all the permissions required and an engineering design completed, last July Kwasi Kwarteng (then the Secretary of State for Business) performed the opening 'ceremony' and also launched the UK's Critical Minerals Strategy. All that is needed now is $550 million to build the mine in Longonjo and the separation plant in Saltend to provide a comprehensive supply network.

The other attractive feature of Saltend is that about 85 miles due east on the Dogger Bank, is the world's biggest wind farm, with one of two supply cables coming into nearby Hull, providing low carbon power for the plant. In Angola the Longonjo mine will be supplied by electricity from a hydroelectric plant on the Kwanza river.

The reason offshore turbines have proved so successful is firstly that the design has done away with the gearbox so they are essentially maintenance free, and that the copper rotor turns inside a 7 tonne RE magnet.

Similarly, the real game changer in an electric vehicle (EV) are the small but powerful magnets in the drive motors. In fact, the entire energy transition from carbon-based fuel to electromotive power depends almost entirely on Nd/Pr/Fe/B magnets, albeit with the addition of Dy and Tb in EVs because they are heat sensitive – not needed in the offshore environment.

With time, turbine magnets lose their power (degaussing?) but with a pleasing synergy, Norwegian company Equinor is heavily involved in the installation of the Dogger Bank wind turbines and is also based on the Saltend chemical park. Equinor also generates hydrogen from natural gas and hydrogen can be used for recycling Nd/Pr magnets, in effect creating a low-carbon, high value economy.

The first stage in raising finance for the project was to de-risk it by drilling, bearing in mind that there were clear parameters: mapped carbonatitic pipes with fenitised margins, earlier (1960s) trenching and good geochemical results. About $5m was raised for the drilling and results were encouraging, which led to the second phase requiring a further $15m, half of which was raised from fund manager Fidelity in London.

The next requirement was metallurgical testing, so both incremental value and lowered risk had been demonstrated at each step in the process, and Paul himself has always believed in putting his own money into a project. Other highly favourable factors were that the Longonjo mine has the refurbished Benguela railway nearby which goes to the coastal port of Lobito, carbon-free electricity available from the hydro plant on the Kwanza river, and the Angolan National Wealth Fund is the biggest single investor. All these factors have been vital for subsequent investments.

The likelihood is that Pensana will become capable of challenging the Chinese RE processing hegemony, and in doing so, creating a unique circular economy as well.

John Bennett