Front Cover Image – Liquation Cracking

Image shows a nickel based superalloy experiencing liquation cracking from the welding process. In this example IN617B parent metal, right hand side of image, with matching filler weld metal on the left. A series of stringers, i.e. aligned broken oxides or carbides, run up the image showing the direction of pipe extrusion.

Liquation occurs in the heat affected zone of the weld where the temperature is higher than the low melting point elements phases found at the grain boundaries. These liquid phases can diffuse away into the grain or the mussy zone can have insufficient strength to prevent fracture, i.e. nil strength or nil ductility.

These cracks can be several hundreds of microns in length and scattered along the fusion line. Nickel alloys tend to be difficult to examine by ultrasonic techniques so these cracks often go undetected since the only real method of detection is by metallographic examination.
EMG Newsletter Lead - EU Emissions Trading System (EU ETS)

The EU emissions trading system (EU ETS) set up in 2005 is a cornerstone of the EU’s policy to combat climate change and its key tool for reducing greenhouse gas (GHG) emissions cost-effectively. It is the world’s first major carbon market and remains the biggest one. The EU targets are to reduce GHG by 20% by 2020 and 40% by 2030 compared to 1990 levels.

The system covers the following sectors and gases with the focus on emissions that can be measured, reported and verified with a high level of accuracy:

- carbon dioxide (CO₂) from
  - power and heat generation
  - energy-intensive industry sectors including oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals
  - commercial aviation
- nitrous oxide (N₂O) from production of nitric, adipic and glyoxylic acids and glyoxal
- perfluorocarbons (PFCs) from aluminium production

Participation in the EU ETS is mandatory for companies in these sectors.

EU ETS operates in 31 countries (all 28 EU countries plus Iceland, Liechtenstein and Norway) and limits emissions from more than 11,000 heavy energy-using installations (power stations & industrial plants) and airlines operating between these countries and covers around 45% of the EU’s greenhouse gas emissions.

The EU ETS works on the 'cap and trade' principle.

A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall.

Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value.

After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. Trading brings flexibility that ensures emissions are cut where it costs least to do so. A robust carbon price also promotes investment in clean, low-carbon technologies.

Delivering emissions reductions

The EU is on track to meet its emissions reduction target for 2020 and is putting in place legislation to achieve its 2030 target. In 2015, the EU was responsible for 10% of world greenhouse gas emissions. EU emissions were reduced by 23% between 1990 and 2016, while the economy grew by 53% over the same period. For 2016 EU emissions decreased by 0.7%, while GDP grew by 1.9%.
The EU is one of the major economies with the lowest per capita emissions. The EU and its Member States have met their commitments under the Kyoto Protocol’s first commitment period, i.e. 20% reduction by 2020. Will the EU meet its targets under the second commitment period of the Kyoto Protocol, i.e. 40% by 2030? If you see graphic below even with “additional measures” the target looks a bit of a stretch. The expected third commitment period of 80% reduction by 2050 (still to be ratified) looks like a real challenge.

How About the UK

In 2008, the UK enshrined in law a series of targets, namely to reduce its GHG emissions relative to 1990 by 26% - 2012; 32% - 2017; 38% - 2022; 52% - 2027; 57% - 2032 and 80% - by 2050. At the latest audited figures UK emissions were 43% below 1990 levels in 2017. As such the UK is ahead of its targets as per the below graphic. The bad news is that little progress has been made in transport, farming and buildings. “The success in the power sector has masked failure in other areas,” (New Scientist 28th June 2018).

The introduction of electric vehicles will help the transport sector hit its targets but to achieve the 80% target farming and aviation will need to significantly make improvements. The UK Climate Change Committees figures for the residual UK GHG by 2050 are also shown below. As you can see a lot is riding on Carbon Capture and Storage, CCS, and agriculture and aviation will continue to be big GHG contributors. In future editions we will look in more detail at these 3 areas

Dr Peter Barnard
Member of EMG and Editor of Newsletter
EMG Newsletter Lead – Continued

Figure 1.1. UK carbon budgets and the cost-effective path to the 2050 target

Source: CCC calculations.
Notes: Historical emissions are on a ‘gross’ basis (i.e. actual emissions). Carbon budgets are on the current budget accounting basis, excluding international aviation and shipping (IAS), but allowing for IAS in the 2050 target.

Figure 3.1. Residual UK greenhouse gas emissions in 2050 under Max deployment across all sectors

Source: CCC calculations.
Energy Materials Information Streams

The EMG microsite is a mine of information relating to Energy Materials with links to various sources of information, including funding sources for collaborative research/development.

The EMG microsite is actively managed and regularly updated; the link to the appropriate location on the microsite is given below


Materials Today Energy, Volume 9, Sept 2018

- Aging effects in interface-engineered perovskite solar cells with 2D nanomaterials: A depth profile analysis
- Exploring two dimensional C_{0.33}In_{2.67}S_{2.29}Se_{1.71} as alloy type negative electrode for Li-ion battery with olivine LiFePO_{4} cathode
- Gradual “OH−-incursion” outside-inside strategy in construction of 3D flower-like Co_{3}O_{4}-CNT>N-PEGm hierarchical microspheres for supercapacitors
- Kinetic insights into the reduction of ceria facilitated via the partial oxidation of methane
- Comparative study of edge-functionalized graphene nanoplatelets as metal-free counter electrodes for highly efficient dye-sensitized solar cells
- NiMn layered double hydroxides derived multiphase Mn-doped Ni sulfides with reduced graphene oxide composites as anode materials with superior cycling stability for sodium ion batteries
- A new insight towards eggshell membrane as high energy conversion efficient bio-piezoelectric energy harvester
- GeP_{3} with soft and tunable bonding nature enabling highly reversible alloying with Na ions
- High energy density, robust and economical supercapacitor with poly(3,4-ethylenedioxythiophene)-CO_{2} activated rice husk derived carbon hybrid electrodes
- Direct observations of liquid water formation at nano- and micro-scale in platinum group metal-free electrodes by operando X-ray computed tomography
- Capacitive lithium storage of lithiated mesoporous titania
- Powerful amorphous mixed metal catalyst for efficient water-oxidation
- TiO_{2} nanofiber photoelectrochemical cells loaded with sub-12 nm AuNPs: Size dependent performance evaluation
- Molecular engineering of ionic type perylenediimide dimer-based electron transport materials for efficient planar perovskite solar cells
- Melamine-sponge-derived non-precious fuel cell electrocatalyst with hierarchical pores and tunable nitrogen chemical states for exceptional oxygen reduction reaction activity
Organisation Profile

Henry Royce Institution

The Henry Royce Institute, HRI, has been established to develop and exploit the UK's world-leading excellence in advanced materials research. Operating with its Hub at The University of Manchester, the Henry Royce Institute is a partnership of nine leading institutions – the universities of Cambridge, Imperial College London, Liverpool, Leeds, Oxford, the National Nuclear Laboratory, and UKAEA.

The Royce co-ordinates over 900 academics and over £300 million of facilities, providing a joined-up framework that can deliver beyond the current capabilities of individual partners or research teams. The initial science program targets nine core themes, each led by a champion and coordinated through a stakeholder network of industrialists and academics.

2D Materials: Led by the University of Manchester to understand atomic thickness materials, including graphene, for a range of applications including membranes for filtration and coatings, energy storage and functional composites.

Advanced Metals Processing: Led by the University of Sheffield to create new alloys with higher performance, better manufacturability, greater flexibility, lower cost, and lower environmental impact for use in materials systems across transport, healthcare, energy, and manufacturing.

Atoms to Devices: Led by the Universities of Leeds and Imperial College for quantum scale engineering of new technologies, that can translate into applications including photonics, imaging, semiconductors, sensors, energy storage and biomedical materials.

Biomedical Materials: Led by the University of Manchester exploring new generation ‘smart’ biomaterials that improves health and wellbeing. This includes two grand challenges of; restoring biological function with minimal invasiveness, and new, low risk, cost efficient therapies.

Chemical Materials Design: Led by the University of Liverpool to discover and analyse new chemical materials by combining high performance computing and materials science to impact a wide range of sectors, from nanofabrication to nuclear engineering.

Energy Storage: Led by the University of Oxford with research focused on batteries, supercapacitors and thermoelectrics to solve the material challenges involved in the all-solid-state battery to transform the safety of lithium-ion batteries and energy density.

Materials for Demanding Environments: Led by University of Manchester for research into performance and degradation to enable the design of new materials, systems and coatings for a range of applications including energy, marine, aerospace and automotive.

Materials for Energy Efficient ICT: Led by the University of Cambridge to focus on innovation in energy generation, storage and use, to transform the devices we use. Applications include solar coatings, reduced power consumption, and battery energy density, longevity and cost.

Nuclear Materials: Led by the University of Manchester aimed at nuclear fuels and waste streams in the nuclear fuel cycle; and structural materials for fission and fusion energy. This will drive productivity, lower cost and improve safety in future nuclear programmes.

For more information on the activities of FI please visit https://faraday.ac.uk/
Editor’s Titbits Section

Could graphene see metal-air batteries become commercial?

Indian start up Log 9 Materials seems to think so – the firm, which is a spin-off from the Indian Institute of Technology Roorkee, suggests the wonder material could solve the issue of range anxiety frequently associated with battery-powered vehicles.

Metal air batteries powered by water, air and metal generate energy in much the same way as a fuel cell, in contrast with conventional lithium-ion batteries, which store energy rather than producing it. The technology has ten times more energy density than traditional alternatives, meaning it is able to provide a range of more than 1,000 kilometres. Log 9 Materials aims to use graphene to make such batteries commercially viable and economical and metal is recyclable once it has been used in the battery to generate energy.

Rolls-Royce targets electric flight speed record

A partnership led by Rolls-Royce is building a low carbon aircraft it hopes could shatter the electric speed record by reaching more than 300mph. The Accelerating the Electrification of Flight (ACCEL) programme, which is partly funded by the UK Government, is expected to become operational by 2020.

The companies involved hope it will be able to beat the previous record of 210mph set in 2017 by Siemens. The single-seater propeller-aircraft will use a battery pack of 6,000 cells, which Rolls-Royce claims is the most energy-dense energy storage unit to have ever been installed in a plane. This will allow it to generate 750kW of power, enough to supply around 250 homes, while boasting a range capable of flying from London to Paris.

Battersea Power Station to generate power after 35 years

The Battersea Power Station Development Company (BPSDC) has announced a new energy centre for the 42-acre regeneration site. The underground equipment will be used to supply heating, cooling and electricity. The structural build is now complete and will be kitted out by Vital Energi by 2020.

The project has excavated 150,000 cubic metres of earth, poured 16,000 cubic metres of concrete and installed 4,200 tonnes of steel framework to reach the current stage. The energy generation infrastructure will be made up of three combined heat and power (CHP) gas-fired engines totalling 7.3MW, three 10MW gas-fired boilers, seven thermal stores and six 4MW chillers.

Fossilised algae provide longest global warming timeline

Fossilised algae could provide the best historic record of changing global temperatures over the last 500 million years. Scientists at the Netherlands Institute for Sea Research (NIOZ) and Utrecht University found that using the organic molecule phytane, it is possible to reconstruct the geological past and paleoclimate to make better predictions about future climate conditions.

The product of chlorophyll serves as an indicator of ancient carbon dioxide levels, providing the most continuous record of greenhouse gas concentrations ever, according to the researchers. It
allows a longer time period to be studied than using ice cores, which have a limited time span of a million years. The data shows historic levels of carbon dioxide, reaching 1,000 parts per million as opposed to today’s 410 parts per million. The data also confirms the idea that rises in carbon dioxide levels that used to take millions of years are now happening in a century.

**Germany commits to ending coal power by 2038**

Germany is to shut down all 84 of its coal-fired power plants by 2038. The plan is expected to cost around $45 billion (£34.2bn), which will be spent to help protect regions which depend on coal power. The first stage of the coal shutdown will see a quarter of the country's coal-burning plants to be shut down in the next three years.

Coal currently accounts for around 40% of the country's electricity, only being overtaken by renewables as the primary source of power last year. It is thought Germany will have to rely on renewable energy to provide 65% to 80% of the country’s power by 2040, after having already decided to shut down all of its nuclear power plants by 2022.

**Plastics from olive seeds**

An Istanbul-based team of entrepreneurs have developed a method to turn olive seeds into sustainable bioplastics. Biolive claims to have created a new product which could help take the place of environmentally-intensive plastics.

The firm uses the cellulosic agent in olives to create green alternatives for use in electronics and food product packaging – taking advantage of waste products from olive oil factories, the firm can create 3.5 tonnes of green plastic from around five tonnes of olive seeds.

**Electronic waste worth $62bn**

The value of electronic waste produced each year totals $62 billion (£48bn), triple the value of all silver produced annually. A new report from the World Economic Forum and the UN’s E-waste Coalition claims the world is on the brink of a major health and environmental crisis and predicts the annual amount of electronic waste produced will increase from 50 million tonnes today to 120 million tonnes by 2050.

Currently, only a fifth of the electronics and plastics thrown away are recycled, despite there being 100 times more gold in a tonne of mobile phones than in a tonne of gold ore.

Editor’s Note: The source of many of these titbits is *Energy Live News*. 
Mini Feature

Massive, Gravity-Based Battery Towers Could Solve Renewable Energy’s Storage Problem

Renewable energy is billed as a clean source of power but it has a problem. Renewables harness the power of the sun by extracting energy from the endless stream of solar rays that pound Earth’s surface and the winds that course over it. Yet, the sun is often shrouded by clouds (or completely out of sight, at night) and winds ebb and flow. If the transition to renewables continues — replacing the regular, fixed power output of coal, gas and nuclear plants with more intermittent and unpredictable sources of clean energy — how will energy providers ensure a steady supply of electricity?

The answer may lie in towers of massive concrete blocks stacked hundreds of feet high that act like giant mechanical batteries, storing power in the form of gravitational potential energy. This new energy storage concept is being advanced by a Californian/Swiss start-up company called Energy Vault as a solution to renewable energy’s intermittency problem. The towers would store electricity generated by renewables when their output is high in windy, sunny conditions and release energy back to the grid when production falls as winds die down and clouds move in.

Gravitational Batteries

Topping each tower are cranes that raise and lower thousands of the stackable concrete blocks, each weighing 35 metric tons. Excess grid electricity powers motors in the crane to lift the blocks, picking them up from an outer ring of extras and hoisting them to the top of an inner concentric ring. To deliver electricity back to the grid, the potential energy of the raised blocks is harnessed. The cranes pick them off the summit of the inner ring and drop them back down to the outer ring, converting the kinetic energy of the falling masses into electricity with generators as the blocks fall.

A standard tower has a 35 MWh capacity with a 4 MW peak power output that can be modulated based on demand. Energy Vault claims 90% round-trip efficiency, which is enabled by mechanical simplicity grounded in fundamental physics directed by an intelligent control scheme. The specific positioning and motion sequences of the crane are fully autonomous, controlled by custom software algorithms that take into account wind conditions and the inertia of the massive blocks to place them in the most efficient configuration possible.
The concept takes inspiration from pumped hydroelectric energy storage, in which water is transferred between two reservoirs at different elevations. With this approach, surplus electricity is used to pump water to the higher elevation to be later converted back into electricity by releasing it to flow through a turbine as it falls back to the lower reservoir. Compared to Energy Vault’s towers, however, pumped hydro is geographically limited by its topography requirements. Its reservoirs take up a lot of space and must be situated in locations with large, naturally occurring elevation changes. A tower requires less surface area and can be placed nearly anywhere there is reasonably flat ground.

In addition to supplying a flexible reserve of energy to compensate for the intermittency of renewables, the towers have the potential to provide other important ancillary services to maintain grid stability and reliability. Tower generation ramps up within milliseconds and reaches full power output in 2.9 seconds. The quick response represents another advantage over sluggish pumped hydro and opens the possibility of towers serving as rapid-response power sources in place of traditional solutions like generators. In this role, the towers could deliver regulation services, equalizing brief imbalances in the electrical grid such as frequency or voltage discrepancies. They could also provide black start services in the event of a grid outage, helping to restore power by supplying the minimum energy that some grid elements such as large generators required to start back up.

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Mini Feature

Wind Turbine Blades with a Twist Are Undergoing Tests

Three innovative 20 metre long rotor blades with a novel bend-twist coupling will be tested over the next four months in an effort to learn how effective the blades are at dampening peak loads during strongly variable wind speeds. Rotor blades equipped with bend-twist coupling are able to adapt to variable wind conditions by themselves; at higher wind speeds the blades can bend or twist, thus offering the wind a smaller impact surface.

The smaller surface is intended to reduce the overall load on the system, potentially increasing the wind turbine’s life and its power yield. In order to fully capture the structural and aerodynamic behavior of the blades during the field experiment, the project partners integrated measurement systems into the blades’ structure.

The blades, developed as part of the SmartBlades2 project, were designed by the Fraunhofer Institute for Wind Energy Systems and built by the German Aerospace Center. They will be tested at the U.S. Department of Energy’s National Wind Technology Center, part of the Colorado-based National Renewable Energy Laboratory.

The SmartBlades2 project is funded by the German Federal Ministry for Economic Affairs and Energy and is being carried out by the Research Alliance Wind Energy, with partners DLR, Fraunhofer IWES and ForWind. Industry partners include GE, Henkel, Nordex Acciona, SSB Wind Systems, Suzlon, Senvion and WRD Wobben Research and Development.

Inside the rotor blades, systems will continuously control how the blades behave under the diverse wind loading conditions the turbine will test. The turbine’s tower and the nacelle, made available by NREL, are also equipped with measuring technology, enabling the team to measure the whole system’s behaviour in detail.

The resulting measurements will be correlated with data on wind conditions, which will be recorded by NREL data acquisition systems and a Spinner lidar (light detection and ranging) measurement device. This lidar is normally installed in the spinner of a wind turbine. For the NREL tests, the device will rest on top of the nacelle to analyse the wind field both in front and behind the turbine.

Researchers said that comparing the structural behaviour measured by the sensors with the wind data will show whether the rotor blades achieve the desired behaviour. On site — at the edge of the Rocky Mountains northwest of Denver — the wind conditions can range from very low speeds to powerful gusts in winter and early spring. This will make it possible for the researchers to assess the SmartBlades2 rotor blades under a variety of environmental conditions.

Design validation will start with data analysis while measurements are still being conducted, and will continue until the autumn of 2019. The project is intended to help support the wind energy industry in developing rotor blades with bend-twist coupling and may pave the way to implement this technology.

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Upcoming Events

NEXT COMMITTEE MEETINGS
11:00 6 February, IOM3, 297 Euston Road

EMG WORKSHOPS/CONFERENCES

Parsons 2019, 16–18 September 2019, Cranfield University, UK

OTHER WORKSHOPS/CONFERENCES/COURSES OF INTEREST

Hume-Rothery Seminar, Computational Materials Chemistry, 12–13 Feb 2019, Derby, UK

Gordon Conference, Nanomaterials for Applications in Energy Technology, 24 Feb–1 March 2019, Ventura, USA


1st EPERC International Conference, 1-3 April 2019, Rome, IT

PV SAT 15 Photovoltaic Science, Applications and Technology Conference, 10-12 April 2019, Warwick, UK

29th Journées des Actinides, 14-18 April 2019, Erice, IT

2019 MRS Spring Meeting, 22-26 April 2019, Phoenix, Arizona, USA

High Temperature Materials Processing Workshop, 22 May, Warwick, UK

Baltica XI - International Conference on Life Management and Maintenance for Power Plants, 11-13 June 2019, Baltic Sea, FI/SE


CCT2019 The International Conference on Clean Coal Technologies, 3-7 June 2019, Houston, USA

NECEM International Conference on Energy Materials & Interfaces, 29 July–1 Aug 2019, Newcastle, UK

Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, 8-22 Aug 2019, Boston, USA

24th International Conference on Advanced Materials and Nanotechnology, 19 – 20 Sept 2019, Brussels, BE


ECCC2020, 14–16 Sept 2020, Edinburgh, UK