RCEA
(SUSSEX)

An Association for Retired Professional Engineers

NEWSLETTER March 2018

President's Message

Welcome to the March Newsletter.

Your committee has been working hard and you will see in the Newsletter that we have a greater number of visits than in previous years, which I hope you will find of interest. Most have restrictions on numbers so my advice is to apply early.

I hope you can join us for the Spring Lunch at Northbrook College on Wednesday 18th April. The meal is good value for money and supports the students in developing their 'silver service' skills.

The following week we have a tour of the AMEX stadium at Falmer. This is one that the ladies might also find interesting to learn what goes on behind the scenes at a Premier Division football stadium.

The Facebook Group (Club) named RCEA (Sussex) has had a slow start. We are hopeful that members will 'take the plunge' and join the Group and make use of the ability to exchange information on a variety of subjects.

Derek Webb

PROGRAMME OF EVENTS 2018

Wednesday	**18th April**	**Spring Lunch**
Thursday	**19th April**	**Coffee – at Spotted Cow, Angmering**
Tuesday	**24th April**	**Outing – Amex Stadium, Brighton**
Thursday	**26th April**	**Coffee – with Partners at Swallow's Return**
Thursday	**3rd May**	**Visit – Ford Technical Centre, Dunton (fully booked)**
Thursday	**17th May**	**Coffee – at Spotted Cow, Angmering**
Thursday	**31st May**	**Coffee – with Partners at Swallow's Return**
Thursday	**7th June**	**Visit – Three Bridges Maintenance Facility**
Thursday	**21st June**	**Coffee – at Spotted Cow, Angmering**

Thursday	**28th June**	**Coffee – with Partners at Swallow's Return**
Thursday	**5th July**	**Visit – Volk's Electric Railway**
Tuesday	**17th July**	**Visit – Case New Holland tractor plant**
Thursday	**19th July**	**Coffee – at Spotted Cow, Angmering**
Thursday	**26th July**	**Coffee – with Partners at Swallow's Return**
Thursday	**16th August**	**Coffee – at Spotted Cow, Angmering**
Thursday	**30th August**	**Coffee – with Partners at Swallow's Return**
Thursday	**9th August**	**Coffee – at Spotted Cow, Angmering**
Thursday	**30th August**	**Coffee – with Partners at Swallow's Return**
Tuesday	**18th September**	**AGM & Talk – We plough the Fields and Clatter!**
Thursday	**20th September**	**Coffee – at Spotted Cow, Angmering**
Thursday	**27th September**	**Coffee – with Partners at Swallow's Return**
Tuesday	**9th October**	**Talk – Artificial Intelligence and the Two Singularities.**
Thursday	**18th October**	**Coffee – at Spotted Cow, Angmering**
Thursday	**25th October**	**Coffee – with Partners at Swallow's Return**
Tuesday	**13th November**	**Cooch Memorial Lecture – Fusion Power – within our Grasp?**
Thursday	**15th November**	**Coffee – at Spotted Cow, Angmering**
Thursday	**29th November**	**Coffee – with Partners at Swallow's Return**
Tuesday	**11th December**	**Talk – Aspects of Marine Propulsion (title tbc)**
Thursday	**20th December**	**Coffee – at Spotted Cow, Angmering**
Tuesday	**8th January 2019**	**Talk – British Tanks – a Relative Success in Combat but Engineering and Procurement Failures?**

All Talks and Meetings will commence at 2.30 pm and be held in the Chichester Room, Field Place, Worthing unless another venue or time is indicated.
Timings for visits and outings will be as printed in the detailed description of the activity.
Coffee mornings commence at 10.30 am.

Website of the RCEA

Our website, **www.rceasussex.org.uk** carries the very latest information on all of our events. As we occasionally have to make last minute changes to our programme due to matters beyond our control, we recommend that you always consult our website.

New Members and Speakers for Talks

The RCEA needs new members to ensure that we can continue as a thriving organisation. Please think of appropriate people you know and encourage them to come along to our talks and hopefully join the RCEA.
We also need more members to give talks to us on Tuesday afternoons from September to March. We are aware that many members have the knowledge from their working careers to provide interesting talks. If you are willing to give a

talk please let us know. Speakers from outside organisations are increasingly harder to find and often seek payment for their services.

New Members

J.Olney, MB BS, FRCR

C.Spiller, MSc, B A (Hons), DipTS(London), MCILT, MCIPS, FRGS

Membership Data

Your committee is currently looking into the possible implications of the forthcoming changes to the General Data Protection Regulations on the way that we record, store and publish information concerning our members. We hope to be able to present more information on this topic at our next AGM.

RCEA Insurance

Members need to be aware that the insurance policy that the Association holds is solely for the protection for the assets and liabilities for the Association as an entity. The policy does not provide cover for personal injury or loss to individual members. Members attend the Association's events at their own risk, although under some circumstances there may be some cover from the insurance arrangements of the venue owner.

SOUTHERN RETIRED CHARTERED ENGINEERS

We have received the following details of the above association's programme. Members wishing to attend any of their functions should contact the Hon Secretary, Jeff Williams at jagwilliams@waitrose.com

Thursday 26th April - Salisbury Playhouse to see "Moonfleet"
Wednesday 16th May - Guided tour of Winchester
Tuesday 5th June - Guided tour of Wimbledon Tennis Complex
July – possible visit to Crofton Beam Engine.
Thursday 23rd August - visit to Gilbert White's House
August – Possible visit to Watermill Theatre.
Tuesday 11th September – visit to Lacock Abbey Museum
Tuesday 2nd October - AGM at Potters Heron Hotel, Ampfield
November - Possible visit to Salisbury Playhouse

Brief Detail – Talks, Visits and Outings April 2018 – January 2019

Spring Lunch
Wednesday 18th April 2018, Northbrook College, Worthing, 12.00 for 12.30

This occasion is not only an opportunity for new and existing members to meet socially, but also provides 'work experience' to chefs and waiters studying at the college.
There will be a bar for pre-lunch drinks, the cost to be settled individually by members and guests. The cost of the three course meal is £15 per head including a tip, which in the past has proved to be very good value. Applications should be made by 1st April 2018.

Should the numbers exceed the maximum seating allowed there will be a waiting list, as in previous years, so please book early to avoid disappointment. The committee look forward to seeing you there.
Booking form is at the end of this newsletter.
Contact George Woollard - 01903 523640, e-mail Georgewoollard1@hotmail.co.uk

Outing
Tuesday 24th April 2018 – AMEX Stadium Tour

The tour of the stadium, which will be of interest to both members and guests, lasts approximately 1 hour and 45 minutes and will commence at 11.00am.
You will visit the hospitality lounges, trophy room, press area, changing rooms and the museum. On arrival at the stadium, you will be directed where to park and the meeting point.
Although the tour is booked for Tuesday 24th April, the stadium maintains the right to change this date if anything unforeseen occurs. You will of course be notified of any change well in advance.

Reply Slip is at the end of Newsletter.

Visit.
Thursday 3rd May 2018 – Ford Research and Development Centre - Dunton, Essex.

We have been able to arrange a return visit to Dunton where we will be able to view the equipment and techniques used to ensure that Ford cars of the future meet specific worldwide regulations, performance and durability targets, marketing and customer requirements etc. The equipment includes many **engine and emission dynamometers (at least one with atmospheric control)**, environmental wind tunnel, **test tracks**, styling studios, machine shops, **many durability rigs for body and chassis components** etc. Exactly what we will be shown will depend on the confidentiality of the vehicles being tested but I have requested the areas highlighted above. Cameras will not be permitted. Only 15 places are available, so we will have to award places and reserves according to the time we receive the reply slips. RCEA members will have priority over guests. Unfortunately travel time will be longer than normal visits (approximately 100 miles via the M25) and attendees will be responsible for their own travel arrangements. Members may wish to car share. The tour starts at 13:15pm. There are a few eating places within easy reach of Dunton and suggest that we meet at around 12 o'clock at one of them (to be selected nearer the time). Currently this visit is fully booked, but any member wishing to be placed on a waiting list can contact Ivan Farrow 07971184207, e-mail ivan_farrow@yahoo.com.

Visit
Thursday 7th June – Three Bridges Maintenance Facility

The recently opened Three Bridges train care and maintenance facility is 1.4 miles long and has stabling capacity for 172 carriages. It's home to the new Siemens Desiro City Class 700 fleet for the Thameslink route, maintained by Siemens and operated by Govia Thameslink Railways.
Siemens has kindly agreed to host a visit for 20 RCEA members and have offered us lunch, with our group arriving by 11.45. A train from Brighton arrives at Three Bridges station at 11.34 for those travelling by rail.

They need to know shoe sizes for anyone who doesn't have their own safety footwear.

Booking form is at the end of this Newsletter.
Contact Perry Eastaugh 01903 788858, email perry.eastaugh@icloud.com

Visit
Thursday 5th July – Volk's Electric Railway.

The visit will commence at 2pm and will include a guided tour of the Visitor Centre & Workshop before stopping at Magnus Volk's 130 year old office for a private tour and demonstration. After the tours and train ride a special talk on Volk's Engineering Heritage will take place at the Visitor Centre. The visit will last approx. 2 hours and includes return ticket to Black Rock.

Booking form is at the end of this Newsletter.
Contact Perry Eastaugh 01903 788858, email perry.eastaugh@icloud.com

Visit
Tuesday 17th July 2018 – Case New Holland Tractor Plant, Basildon, Essex

We have been able to arrange a visit to this major tractor production plant – the only tractor factory in the UK. It was built in 1964 by Ford and has built over 1.6 million tractors since then. It has been kept up to date with new processes and equipment and a visitor centre. The plant manages extreme complexity successfully: the facility manufactures 14 tractor ranges, 133 models, 12,000 configurations using 9,680 part numbers. In a year, no two tractors that roll off the line are exactly the same. For your information I have attached a link below showing highlights of a visit by a group last year (https://www.youtube.com/watch?v=ktFEj-qeq1M).

Only 15 places are available at £7 each, so we will have to award places and reserves according to the time we receive the reply slips. RCEA members will have priority over guests.

If demand is high it should be possible to organise a further trip or add to the existing trip by special arrangement. Unfortunately travel time will be longer than normal visits, and attendees are responsible for their own travel arrangements. Members may wish to car share. Lunch is available at the visitor centre for an extra £10 and teas/coffees for £1.25. Alternatively visitors may wish to eat en-route. The booking form is at the end of this newsletter.
Contact Ivan Farrow 01903 523640, e-mail ivan_farrow@yahoo.com

Visit
September (date tbc) – National Grid Electricity National Control Centre

Members who heard the talk on the National Grid in February will be aware that the speaker offered to arrange a visit to the ENCC near Wokingham. We are aiming to set this up for late September/ early October. If you would be interested in joining the visit, please let Perry Eastaugh know and he will keep you updated on progress.

Booking form is at the end of this Newsletter.
Contact Perry Eastaugh 01903 788858, email perry.eastaugh@icloud.com

Talk
Tuesday 18th September – "We plough the Fields and Clatter"
Sally Watts

Sally will give us a layman's account of steam ploughing engines as a hobby. She mentioned in conversation with a workmate an interest in steam traction engines. Through that conversation she was invited to join the crew of a 20 ton ploughing engine. This led to a husband, and the acquisition of a Fowler ploughing engine in need of a complete rebuild and experience of steam ploughing under competition and demonstration conditions.

This is a personal account of the hard work and rewards of the steam hobby and the magnificent ploughing engines that fed the country in the First World War, their working, and the people who maintain those few which escaped the cutting torch.

Sally is a professional public librarian and small animal keeper who grew up sharing her father (Ray Parsons)'s love of miniature steam locomotives and the steam preservation movement.

Talk
Tuesday 9th October – "Artificial Intelligence and the Two Singularities".
Calum Chace, author of "The Economic Singularity and Surviving AI".

This talk is about the possibility that the first machine with human-level cognition may be created within a few decades. If and when that happens, it will be closely followed by the arrival of the world's first super-intelligence, and humans will become the second smartest species on the planet. Some years or decades before then, intelligent machines may render most humans unemployable.

Calum Chace thinks these two developments are so radical that they both deserve to be called "singularities", a term borrowed from maths to denote maximum transformation. They are, respectively, the technological singularity and the economic singularity.

The consequences of human-level artificial intelligence (artificial general intelligence or AGI) would be astonishing. The consequences of technological unemployment, if it happens, will also be profound. Both these developments could have wonderful consequences for us – or terrible ones. And the outcome is largely up to us.

Calum Chace is a best-selling writer and sought-after speaker on artificial intelligence. He focuses on the medium- and long-term impact of AI on all of us, our societies and our economies. Before becoming a full-time writer and speaker, Calum had a 30-year career in journalism and business, in which he was a marketeer, a strategy consultant and a CEO.

Talk
Cooch Memorial Lecture – Tuesday 13th November – "Nuclear Fusion – Within our Grasp?"
Robin Stafford Allen FIMechE

We are facing a growing problem with energy for the world population, which is growing at an astounding rate and as the standard of living is also rising, the demand for energy is rising faster than the population growth rate. The vast majority of the world's energy comes from fossil fuel. This cannot continue indefinitely as oil reserves are finite and Global Warming means we may face a serious food shortage if the climate changes radically.

Renewables are providing only a few percent of the energy for the world and almost all renewable with the exception of hydroelectric dams, are "in addition" to power stations and not "instead of" power stations and so cannot be relied upon for "base-load" energy supply continuously.
Nuclear fission has contributed a significant amount to the base-load supply, but there are issues with this technology, and so researchers are examining using Nuclear Fusion, the process that keeps the sun hot, as hydrogen is transmuted into helium releasing energy in the process.

The talk will cover this world energy issue and then move on to showing what Nuclear Fusion is, and how it is being researched using the machines in UK (JET) and the latest machine in France (ITER). Robin will endeavour to show the progress toward putting Fusion generated electricity onto the grid hopefully within our lifetime.

Robin joined Culham in 1992, and has worked in Cryogenics and in the Heating and Fuelling of plasmas on-and-off ever since. He recently spent a sabbatical six years as Director of Engineering for a small tenant company on the Culham site designing and constructing a large 1-metre-bore special superconducting magnet for the AMS-2 experiment (a mass-spectrometer) which was launched on the penultimate Shuttle flight to the International Space Station.
Two years ago he retired from working at CCFE on the mechanical engineering of the plasma-heating equipment for the ITER machine, and the British fusion research effort MAST machine.
He now works part time for the Institution of Mechanical Engineers and lectures part-time on Engineering at Oxford Brookes University.

Reports

Talk
Tuesday 12th December 2017 – "Operation Chastise - No 617 Squadron, The Dambusters"
Dudley Hooley, Director, Tangmere Military Aviation Museum

<u>The Background</u>
In the 1930s Adolf Hitler came to power in a politically fragmented and bankrupt Germany. During the following years it became apparent that Hitler was rebuilding Germany following the First World War and had military ambitions which made the country a threat to those about them and their allies. Most of the central European countries were catalysed (to varying degrees) by these developments and Great Britain commenced a late, but timely, re-armament program.
It is fair to say that the operation to destroy the German dams in the Ruhr began on Tuesday July 26th 1938 at a meeting chaired by Air Vice Marshal W. Sholto Douglas, Assistant Chief of the Air Staff. This was a meeting of the RAF Bombing Committee and one of the main items on the agenda was to bring to the meetings attention a possible weak point in the German industrial economy. This potential weakness was a number of reservoirs that supplied power and water to manufacturing industries which in the time of conflict would be turned over to war manufacture. The object of the meeting was to enquire into the extent to which effective air action against the dams of the reservoirs would be possible. Bombing Committee paper number 16 was circulated and this document described the types of construction and siting of the dams, along with notes on the potential damage that could be caused by a number of the air dropped weapons then available.

Squadron Leader C G Burge, representing the Air Targets Sub-Committee of Aerial Intelligence, reported that the amount of water consumed in the whole of Germany was only three times that of the Ruhr and that the bulk of it was obtained from one large reservoir contained by a single large dam, known as the Möhne Dam. He added that there were also four or five other reservoirs in Germany which fed the inland waterways, the destruction of which was likely to leave the waterways high and dry, which would severely affect the German transportation system.
It also seemed reasonable to believe that the damage caused would be extremely difficult to put right.

At this stage all discussion was about bombing the dams with existing weapons. The largest of these was then the 500lb semi-armour piercing bomb designed to be used against ships. When dropped from a sufficient height, it had penetrated in tests 5ft into concrete and the thickness of a dam at a depth of 40ft was estimated to be approximately 12ft. It was felt that, if a bomb could be driven into the wall to a depth of 5ft, the remaining 7ft should be severely damaged or breached but no discussion was given to special weapons. It was recognised during the meeting that any bomb would be far more effective when placed on the wet side of the dam, rather than the dry side. The possible use of torpedoes was also discussed. The final outcome of the meeting was that at the present time it was considered that the attack should be directed primarily against the high water side of the dam. Attack against the lower side was considered less likely to be effective unless a bomb could be devised that which would develop sufficient striking velocity to achieve the necessary amount of damage at low altitude.
The seed had been sown and then matters rested for three years. In essence however the basis of *Operation Chastise* had been established, namely:

1. that the destruction of the Möhne dam would remove a large percentage of the water required by the Ruhr Valley industries to produce war materials along with a substantial amount of hydro-electricity;
2. that the destruction of the smaller Ruhr dams would cause some loss of electrical power and great disruption to the German inland waterway system upon which a great proportion of German industry and war making capability depended;
3. an additional fringe benefit would be the damage caused to industry and infrastructure by the release of large amounts of water from these reservoirs.

<u>Dr Barnes Wallis</u>
Barnes Wallis was born in 1887 and schooled at Christ's Hospital and Haberdashers' Aske's schools in London. Unable to afford university, he started an indentured apprenticeship at the Thames Engineering Works at Blackheath. In 1908 he transferred to JS Whites shipyard at Cowes IoW, working on Naval destroyers.

He joined Vickers in 1921 and, when the Second World War broke out, Barnes Wallis was Assistant Chief Designer at Vickers Armstrong Aviation Section at Weybridge where, independently of any Air Ministry requirement, he spent some time investigating how the energy sources of the Axis powers (Germany and Italy) might be reduced or eliminated.
Specialist publications provided him with all the necessary background information on the German dams and he formed the opinion that knocking out the water reserves of the Ruhr would curtail steel production severely.
Barnes Wallis was already developing his theories regarding large bombs and these were principally along the lines that a large and heavy bomb dropped from a great height would develop a sufficient velocity to penetrate deep into the ground before exploding, whereupon the shockwave formed and the collapsing camouflet effect formed by the underground explosion would demolish any target either directly over the bomb strike but, more importantly, for some considerable radius around it.

This was important as it was the use of the shockwave from the explosion travelling through the solid media (earth) which caused the main damage.
Barnes Wallis was well familiar with current aircraft design, having designed the Vickers Wellesley and the Vickers Wellington bombers, both at that time in use by the RAF. He was aware that no aircraft existed that could lift a bomb of the weight needed to a sufficient height for his plan to be put into effect. However, he quietly proceeded with his experiments and turned his mind towards reducing the amount of explosive that would be needed to demolish the dams.

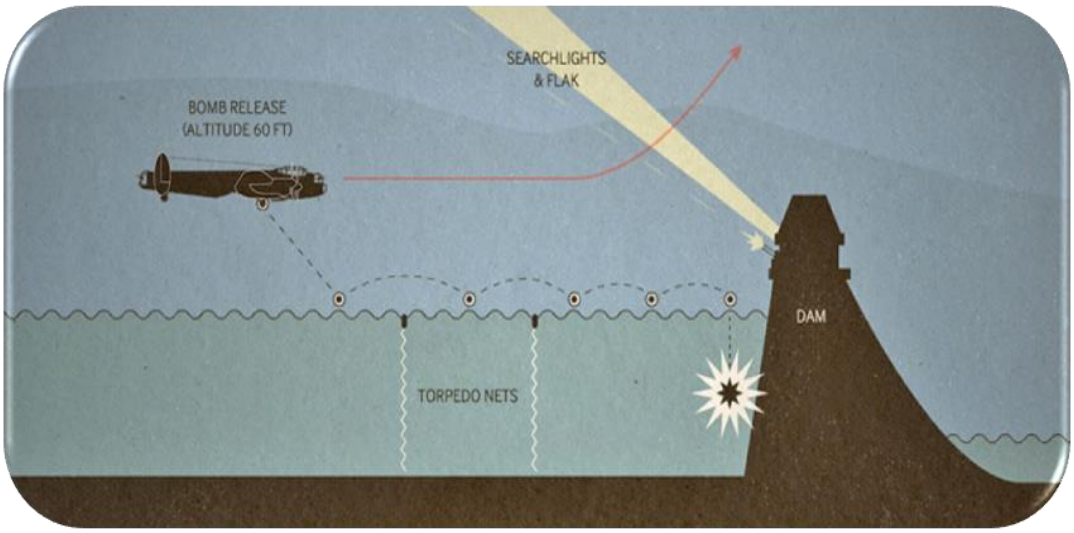
He arranged for scale models of a number of dams to be built, including this replica of the Möhne Dam which still survives in the grounds of the Building Research Establishment at Garston.
The model was built in 1941, 2 years before the raid. Experiments proved that, if a relatively small explosive charge could be placed low down on the wet side of a concrete dam face, the shock wave caused by its explosion travelling through the water would be very much greater than the same explosive on the dry side of the dam and this enabled him to start considering ways and means by which an explosive charge could be placed as required.At the same time as these tests were taking place, Barnes Wallis prepared a paper entitled “A Note on the Methods of Attacking the Axis Powers” which he finalised in March 1941.
100 copies were circulated in military and political circles, the outcome being the formation of a committee, entitled the Aerial Attacks on Dams Committee, to take his suggestions further.
He obtained permission to blow up the Nant y Gro dam in Wales, which had been used to provide power for workers while they were building a bigger dam. On July 24th 1942, 280lbs of explosives were detonated against the wall of the dam at a depth of 10 feet. The blast blew a hole 60 feet wide and 25 feet deep in the dam wall.
The concept of a bouncing bomb was not invented by Wallis himself. Naval gunners in the 16th and 17th centuries discovered they could increase the range of their cannons by 'bouncing' cannon balls off the water like a stone in a pond. There were also reports from pilots early in the war who said that, even if they dropped their bombs short of enemy shipping under attack, they would sometimes skip on over the water and still hit the target under the right conditions. Knowing that he had to get the bombs to detonate right next to the dam wall, Wallis began to experiment with the concept of a bouncing bomb as means of doing so.
Wallis began his experiments with bouncing bombs at his home in Surrey. He used his daughter Elizabeth's marbles to bounce off the surface of a metal tub and land on table further on.

He soon extended his experiments to the National Physical Laboratory ship testing facility at Teddington. Using the 670 foot long water tank, Wallis bounced many different spheres of various design and of various materials including smooth, grooved and even dimpled balls (similar to golf balls). In his experimentation he discovered that the ball must hit the water at a certain angle otherwise it would dive straight into the water without bouncing. The critical angle for the ball to bounce was about 7 degrees. This angle of impact had great implications as to the height from which the bomb would have to be dropped. Wallis also discovered that applying backspin to the sphere gave better results. If the sphere was spun backwards, it bounced better because it was more inclined to rise off the surface of the water. The backspin also increased the distance the sphere would travel due to the improved bouncing effect.
Also, after a certain number of bounces, the sphere would decelerate enough so that it would sink at the wall of the dam and not overshoot.
After encouraging results from the test tank in Teddington, Wallis took his ideas, along with the test results, calculations and designs to the Air Ministry, the Ministry of Aircraft Production, the Admiralty and Vickers who he worked for. He was told to construct and test six half size prototype weapons– they had the code name *Upkeep*. On December 4th 1942, using a Wellington bomber piloted by Vickers' chief test pilot Mutt Summers, Wallis dropped his first test bomb

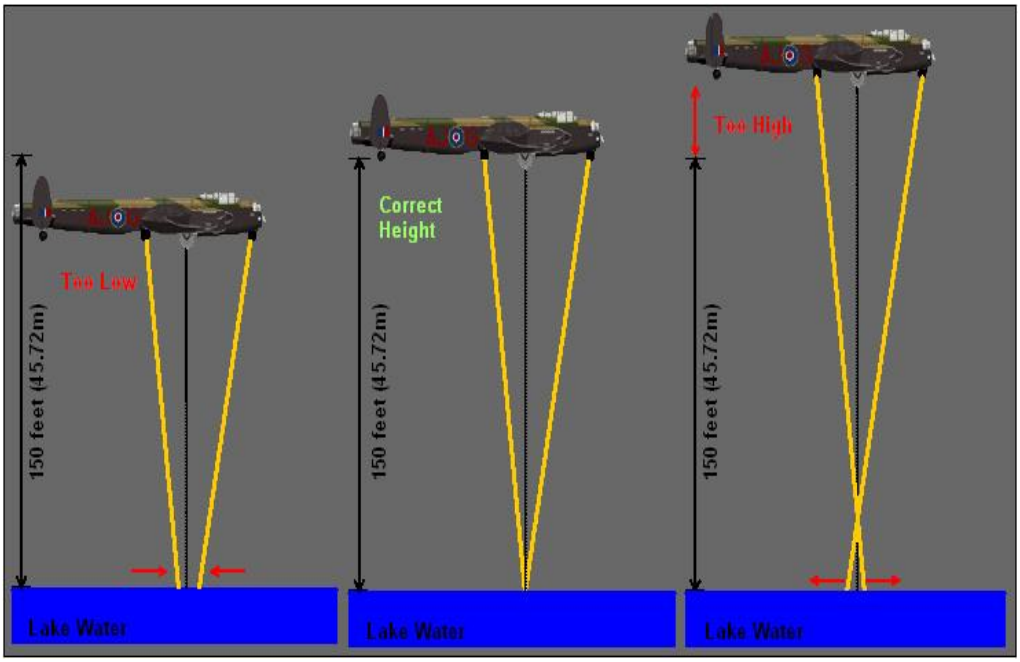
just off Chesil beach in Dorset. After hitting the water, the bomb was torn apart into tiny pieces. All following tests were just as disappointing. The problem was that the casing which gave the weapon its spherical shape continued to break apart despite attempts to strengthen it. Although the casing broke, the bomb did bounce just as Wallis had suggested. He believed that, given time, he could solve the problems with the casing and deliver a fully working prototype of *Upkeep*. Wallis wrote a paper called 'Attacks on Dams' which contained his progress on *Upkeep* and suggested suitable targets. He submitted the report to senior figures in both the military and Government. The response was far from what Wallis was expecting! The Ministry of Aircraft Production felt it could not cope with the manufacture of *Upkeep* along with the production of aircraft which at the time was its number one priority. Furthermore, head of Bomber Command, Air Chief Marshal Sir Arthur Harris, described Wallis' idea as "Tripe of the wildest description". He commented that the revolving mine would tear itself from the bomb bay and destroy the aircraft carrying it. He also said "The war will be over before it works - and it never will". Harris did not want to lose any of his precious Lancaster bombers on a "wild goose chase" that stood little chance of success. He knew from previous attacks just how vulnerable his bombers were.
Luckily for Wallis, Chief of the Air Staff, Air Chief Marshal Sir Charles Portal, who was a central figure in the Air Ministry's earlier plans to attack the dams, had also seen Wallis' results from Chesil beach on film and was very impressed. Portal told Harris to make three Lancasters available for *Upkeep* testing. He told Harris, "If you want to win the war; bust the dams".

<u>Release point calculations</u>

Obviously the "bouncing" bomb would skip across the water in a particular way, but there were still a lot of variables. Wallis needed to ensure the bomb would hit the water and bounce rather than sink, yet still ricochet high enough to clear the German anti-torpedo netting.



He also had to make sure the bounce of the arc wouldn't fall short of the dam, or alternatively clear it entirely and promptly blow up the low-flying plane that had dropped it! After quite a bit of maths, Barnes Wallis calculated that the bomb needed to be dropped exactly 425 yards away from the dam, exactly 60 feet from sea level, while the plane was travelling at 222 miles per hour. (Initially, he had thought that the bomb could be dropped from 150 feet, but later had to revise this to 60 feet). As tests with spherical bombs had proved unsuccessful, a cylindrical design was selected and developed for the task. It weighed 4.2 tonnes and carried 3 tonnes of Torpex explosive. An electric motor spun the bomb up to 500 rpm before it was released.
This would be a hell of a feat even with modern technology. The Lancaster had a wingspan of 31 metres, which was actually greater than the distance from the underside of the plane to the water at the required altitude. This meant there was hardly any room to turn, even with the Lancaster's impressive manoeuvrability. Ensuring this altitude was not a simple task in a Second World War-era plane. The problem was that the standard altimeter was useless at levels below 150 feet. On March 28th 1943 Gibson had flown over the Derwent reservoir to see how difficult it was to fly over water at 150 feet with hills all around. During the daylight he had no real problems but when dusk came he could not distinguish the horizon from the water surface and nearly flew into the lake.
The solution to flying accurately at low level was found by the Royal Aircraft Establishment. A year earlier they had been experimenting with spotlights fitted under Hudson bombers in order to gauge their height while attacking U-boats at night. It had not worked very well due to choppy waves in the sea but over a smooth lake it might. After experimenting with it for a while, two lamps were fitted, one in the nose and one behind the bomb bay. They were angled so that the two beams would meet when the aircraft was at exactly 150 (or, as it was finally, 60) feet. It would be the job of the navigator to look down through the starboard (right) cockpit window and talk the pilot down until the lamps met at the required altitude.



This seems like a pretty genius idea until you remember that you have just put two enormous spotlights onto your aircraft while flying in a raid on enemy territory, which you're doing at night on the premise that *maybe they won't see you coming*. The craziness of this is magnified when you remember you are flying so close to the water that if you turned too quickly to avoid gunfire that you are helpfully providing a well-lit target for, you've just given the Möhne river one of your plane's wings as a midnight snack.

Having dealt with the issue of altitude, the team now needed a way to quickly calculate distance. This had a surprisingly low-tech solution: using the dam's twin towers as markers, a sight was constructed using two nails on a triangular frame at an angle that, when held to the eye, would obscure the dam's towers when the plane reached the correct distance from the dam. While this was fine in theory, the aircraft vibrations made it difficult to use in practice. Some of the bomb aimers relied instead on Chinagraph marks drawn on the bomb aimer's windscreen. Since the bomb had to be dropped 425 yards away from the dam, with the plane travelling at 222 miles per hour, that gave the pilot approximately twelve seconds to get an airplane that was longer than two and a half school buses clear of the dam they had just launched a 7,500lb bomb at.

<u>Formation of 617 Squadron</u>

Air Chief Marshal Portal gave the go-ahead to form the new elite squadron on 26th February 1943; 30 Lancasters were allocated to the new squadron, and a target date of May 1943 was set for *Operation Chastise*. A new squadron was formed at Scampton on 21st March 1943, initially known as "X" Squadron and latterly as 617 Squadron, and the 24 year old Wing Commander Guy Gibson was personally selected to lead it by none other than Air Chief Marshal Sir Arthur "Bomber" Harris, the Commander-in-Chief of Bomber Command. Gibson had flown 71 bomber sorties and an entire tour of 99 sorties on night fighters and was already the holder of four gallantry awards - the Distinguished Service Order and bar and the Distinguished Flying Cross and bar.

Gibson had 3 weeks to choose the crews for 617 and 8 weeks to train them. Unusually, Gibson had the authority to pick his own crews. They would have to be experienced veterans who had completed or nearly completed two tours. However, although many believe that 617 squadron was formed from the very best, highly decorated pilots and aircrew in the allied force, this was far from the truth. The majority of the squadron had no decorations at all and instead of having flown two tours, some were only one third of the way through their first tour. For some of the flight engineers, the dams raid was their first operational sortie. Gibson personally knew very few of the men including his own crew. Only Flight Lieutenant Bob Hutchinson, a radio operator had flown regularly with Gibson at 106 squadron. They had finished their tour together.

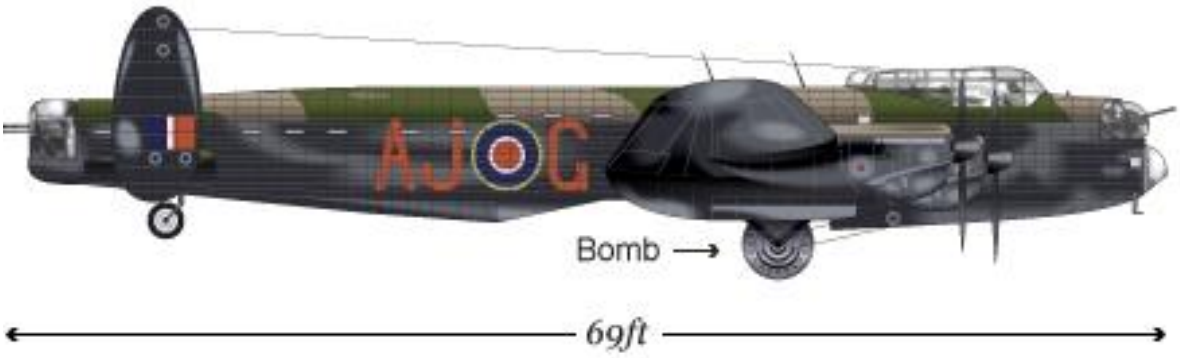
Although Gibson was not told the target officially, he was given a very good idea of what he was up against at a meeting with Wallis on March 24th 1943. This was the first time the two men had met. Wallis could not tell Gibson specific details of the mission as he was not on the list of people with clearance for a full briefing; he did however tell him as much as he could. After the meeting, Gibson left with the knowledge that his aircraft must attack the targets at a speed of 240mph at a height of 150 feet (according to calculations at that time); any variation on this and the plans simply would not work.

The flying was very intensive; night after night they practised, at first in borrowed Lancasters and later in the modified types as they came through from Avro. In order to make conditions as realistic as possible, they were told to fly over three main locations in England: the Eyebrook reservoir at Uppingham in Leicestershire, the Abberton reservoir near Colchester and the Derwent reservoir near Sheffield. It is important to remember that neither Gibson nor the crews were

aware of their targets at this time, the information was absolute top secret and very few people knew. The crews were however beginning to guess what their target may be. At first the rumours were that the target was the German battleship Tirpitz.
While it may seem unlikely for experienced air crews, air sickness was the first problem many of them had when they started training. Flying at low level caused intense turbulent shaking of the aircraft - nothing like having the individual pieces of your plane vibrate so hard its bolts shear! Many of the crews who were used to operating at the rather smoother altitude of 10,000 feet suffered it. The airsickness was so bad that some of the men were prescribed sedatives, as though the mission weren't already complicated enough without the addition of drugs to the mixture.
Each member of the crew had a vital role when it came to dropping the bomb. These were:

- Pilot – control of the aircraft
- Flight Engineer – speed of the aircraft
- Bomb aimer – aiming and release of bomb
- Navigator – passing height information to Pilot
- Wireless Operator – Controlling spin speed of bomb
- Air Gunners – defence suppression

The Lancasters were specially modified to take the bomb, and were known as Lancaster B Mark III Special (Type 464 Provisioning). Their configuration is shown below:



On May 11th 1943, just 5 days before the night of the attack, the squadron began training with actual *Upkeep* bombs at Reculver (although they were not actually filled with explosives). They were amazed to see the drums bouncing over the water right up to the beach. Still they did not know their targets! After seeing the weapon in operation, it reignited talk that the target was the Tirpitz or even U-boats.
The first drop of a fully armed *Upkeep* bomb was made by Sqn Ldr Maurice (Shorty) Longbottom on May 13th from 75ft, five miles off Broadstairs – the location had been changed from Reculver for security reasons. Spinning at 500rpm, it bounced seven times over 'almost 800 yards' without deviation. For this trial the theodolite camera was positioned ashore on the North Foreland almost broadside to the aircraft's track, and Handasyde [another test pilot] flew the other Lancaster at 1,000ft and 1,000 yards away from Longbottom, with two cameramen aboard to operate the normal-speed camera. Handasyde had Gibson as observer, and Wynter-Morgan flew in Longbottom's rear turret to watch the behaviour of the mine after release as it slowed to 55mph behind the aircraft.
The film of this test showed that the water-spout when the mine exploded rose to about 500ft above Handasyde's aircraft, and the estimated depth of detonation was about 33ft. For all concerned the day was eminently successful.
While on training with real *Upkeeps* at Reculver, both Shannon and Maudslay damaged their Lancasters by dropping their bombs too low and being caught in a huge column of water thrown up after it hit the water. By the time the attack came five days later, Maudslay's aircraft could not be repaired and the attacking force was down to 19 aircraft from the 20 originally intended by Gibson. Gibson had picked 21 crews for the squadron, the 20 to fly and one reserve. Coincidently, both Divall and Wilson had sickness and their crews would not fly. This therefore left 19 aircraft and 19 crews. The attacking force had been determined out of Gibson's hands.

On May 15th the Squadron received Permission to Go – immediate attack of targets X, Y and Z (the Möhne, Eder and Sorpe dams) was approved for execution at the first suitable opportunity.

On the afternoon of May 16th Gibson's black Labrador, Nigger, the squadron mascot, ran out into the road outside RAF Scampton and was hit by an oncoming car (which swerved into a ditch in an effort to avoid him) and was killed. At Gibson's request, Ft Sgt Powell buried Nigger at midnight, while Gibson was leading the attack on the dams. His grave is still tended at RAF Scampton to this day.

<u>The Order of Battle</u>
The plan was for the aircraft to fly in 3 waves:

- Wave 1 – 9 aircraft to the Möhne and Eder dams
- Wave 2 – 5 aircraft to the Sorpe, Ennepe Lister and Diemel dams
- Wave 3 – 5 aircraft as backup for Waves 1 and 2

The first wave of nine aircraft (AJ-G, AJ-M, AJ-P, AJ-A, AJ-J, AJ-Z, AJ-L, AJ-B and AJ-N) would take off in three sections ten minutes apart. They would fly a southerly route, crossing the enemy cost at the Scheldt estuary in Holland. Their first target would be the Möhne dam. Wallis believed that only one *Upkeep* would be required to cause a breach in the dam. The planners allowed Gibson to use three, firstly in case one was not enough and secondly to expand the gap. Once the Möhne had been breached, the aircraft that had attacked and no longer had an *Upkeep* would turn back home, while the remaining aircraft with *Upkeeps* would go on to Target B - the Eder. After breaching the Eder, the process would be repeated and aircraft with remaining *Upkeeps* would proceed to Target C - the Sorpe.
The Sorpe would be the primary target of the second wave consisting of five aircraft (AJ-T, AJ-E, AJ-W, AJ-K and AJ-H). The second wave would actually leave Scampton first in order to fly a more northerly route to the Dutch island of Vlieland then down the Zuider Zee and join the flight path of the first wave just over the German border. The two routes were chosen to suggest to enemy radar that these were minor attacks. After attacking the Sorpe, the second wave would use any remaining bombs to attack the secondary targets - the Ennepe, Lister and Diemel.

The third wave of five aircraft (AJ-C, AJ-S, AJ-F, AJ-O and AJ-Y) would leave Scampton more than two hours after the first two waves. They would follow the route of the first wave and act as mobile reserve to attack any of the primary targets that had not been breached or move onto the secondary targets. If all targets had been breached before they reached the Dutch coast, the reserve unit would be recalled.

All crews were warned not to stray from the planned routes because they were designed to avoid flak batteries, night fighter bases and hot-spots all the way from the Dutch coast to the dams and back. They would maintain low level during the whole flight there and back. They were also warned that under no circumstances should anyone return with an Upkeep intact. It was far too dangerous to attempt to land with an armed weapon. They were advised to release the bomb, preferably over German land.

After the briefing, the crews sat down to the traditional eggs and bacon before leaving to make their final preparations for the attack. Some wrote letters to their loved ones in case they did not make it back. Some made final meticulous inspections of their aircraft and weapon and one or two tried to make a last minute phone call, only to find that there was a security cover on all communications of any kind outside of the base.
The map above shows the approximate routes taken by the Dambusters from RAF Scampton to the dams in the Ruhr valley. The black line shows the route flown by the first and third waves. The purple line shows the route taken by the second wave. The red line shows the attack route on the primary targets (Mohne, Eder and Sorpe) taken by all waves.
Note: This map shows locations as in 2003 NOT 1943. It has been used to show the locations of the dams and the route flown to attack the dams.

At 21:28 hours the first aircraft of the second wave (AJ-E) started its take off run. Operation Chastise had begun.

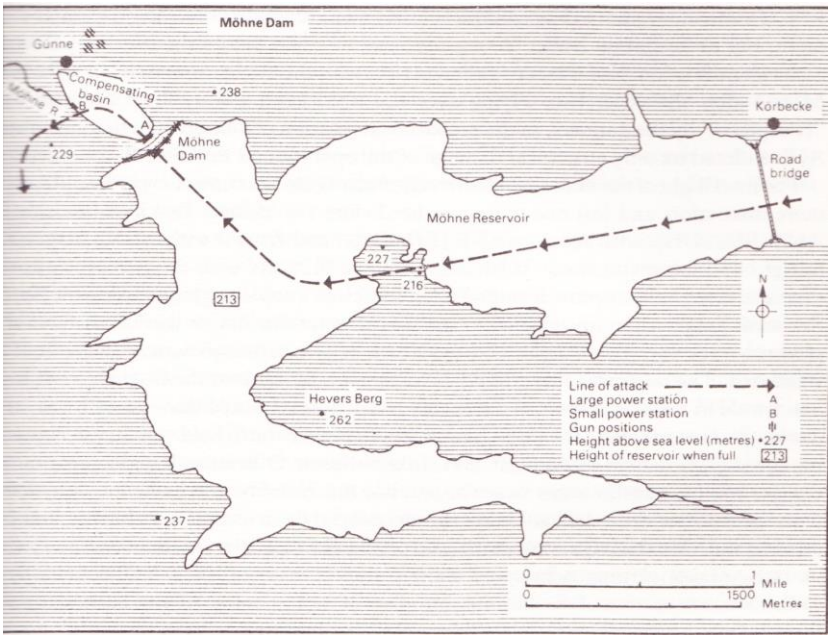
The First Wave

At 21:39 Gibson's Lancaster (AJ-G) took off. As the first wave passed through the Balkan area they encountered heavy flak and intense searchlight activity. This caused Gibson to break radio silence and issue a flak warning which Five Group rebroadcast to all the aircraft shortly afterwards with a detailed position report. There was also heavy flak to the north of Hamme on the approach to the railway marshalling yards.

The second flight of three aircraft of the first wave also encountered flak near Dülmen. The last flight of the first wave encountered stronger headwinds and consequently they were slightly late as they crossed the Dutch boarder into Germany. AJ-B piloted by Flight Lieutenant W. Astell were flying as low as they could to avoid the flak and search lights, but hit high tension wires and pylons 4km from Marbech. The aircraft reared up in the air, burst into flames, but then crashed to the ground. Two minutes later the mine exploded and all seven crew were killed.

Gibson arrived over the Möhne reservoir at 00:15 hours. The aircraft assembled in an anti-clockwise holding pattern 10 km south of Völlinghaussen whilst Gibson called AJ-B on the radio. Astell and his crew were already dead, but he did not know this. Gibson took a few moments to assess the target and its defences. It appeared to be as he had been briefed with three light flak batteries on the dam wall and three more in the valley. Gibson confirmed the attack would be carried out as planned by radio. Using the VHF radio Gibson assigned five of the remaining eight Lancasters to the attack.

Gibson prepared for his run in, the weapon already having been spun up to speed by his W/Op. He first made a dummy run towards the dam to get the lie of the land. He flew through the flak fire before reporting on the VHF that "he liked the look of it".



The attack run had been planned to allow the aircraft time to organise their direction, height and speed before crossing a spit of land that jutted out into the lake and becoming visible to the opposing flak guns. His Lancaster turned out of the holding pattern and directly towards the dam face over the landmark spit of land that guided the run in. They had to fly over the spit at 900ft before diving down to 60ft to release the bomb – the timing was incredibly tight. His bomb was dropped at 00.28hrs and was watched by the rear gunner to bounce three times before exploding against the dam face and throwing a vast column of water into the air. The bomb had struck approximately 150ft off the centre of the face of the dam and the dam had not collapsed.

Hopgood in AJ-M attacked next. The spotlights came on and he commenced his run into the now awaiting flak from the shore and the towers. The Lancaster was hit and started to burn on the port outer engine. Gibson noted damage to the port inner as well. Additionally, the starboard wing had received hits as well and it is little wonder that with these distractions the upkeep was dropped just a few seconds late, it hit, bounced and flew right over the top of the dam wall before exploding with a great violence down by the power generating house in front of the dam wall.

A red very light was fired by Hopgood's W/Op and by now the Lancaster was brightly aflame from a petrol fire. The aircraft climbed to about 500ft and then the strain became too much and the starboard wing collapsed, sending the plane into a dive to crash and explode near the village of Ostonnen, 6km North West of the dam.

Gibson noted that he thought some of the crew may have survived and in fact three survived the crash and two survived to become POW's. Burcher, the rear gunner jumped with his parachute open and in his arms and survived and F/Sgt Fraser, the bomb aimer, also made it out using the same method due to the low height of the aircraft. Minchin, the W/Op, was pushed out by Burcher but the altitude was too low and his parachute did not open in time to save him.

Martin in AJ-P commenced his run with Gibson flying alongside in an attempt to draw away the heavy volumes of light flak coming from the dam. His bomb threw up a similar large plume of water, but again the dam held.

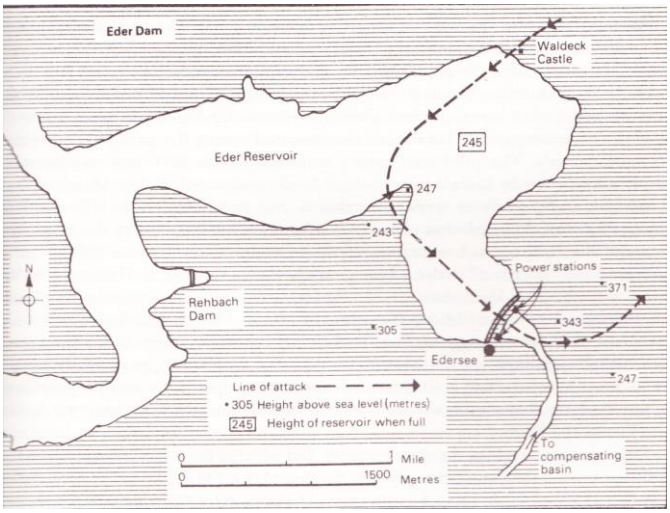
Squadron Leader Dingy Young took the fourth attack in AJ-A. Martin flew parallel with him and instructed his gunners to take on the flak towers to try and reduce the amount of light flak. The guns had been loaded with all daytime tracer ammunition which made the fire appear much heavier than it actually was.

Gibson at the same time turned all of his lights on and flew over the dam from the south in a further attempt to draw the flak away. Again a tremendous plume of water but no break in the dam.

AJ-J piloted by Flight Lieutenant Maltby started his run for the fifth attack. Gibson and Martin flew alongside to take on the flak and Maltby's bomb was perfectly placed. This time a plume of water shot to over 1,000ft into the air before collapsing back into the lake. The dam appeared intact and Gibson ordered Shannon to commence the sixth attack.

Whilst this was happening the main wall of the dam collapsed, revealing an enormous breach through which poured millions of gallons of water. All the anti-aircraft fire, save that from one gun ceased and the code word for a successful breach of this dam (Nigger) was transmitted to bomber command. The aircraft circled for a few minutes watching in awe as the torrent of water travelled down the valley, in some cases with the headlights of cars visibly being overwhelmed by the water and slowly turning green, then brown, before disappearing. The operation, however, had to continue. Maltby and Martin then set course for home whilst the three aircraft still with their *Upkeeps* (AJ-L, AJ-Z and AJ-N) flew to the south east accompanied by Gibson towards the Eder reservoir.

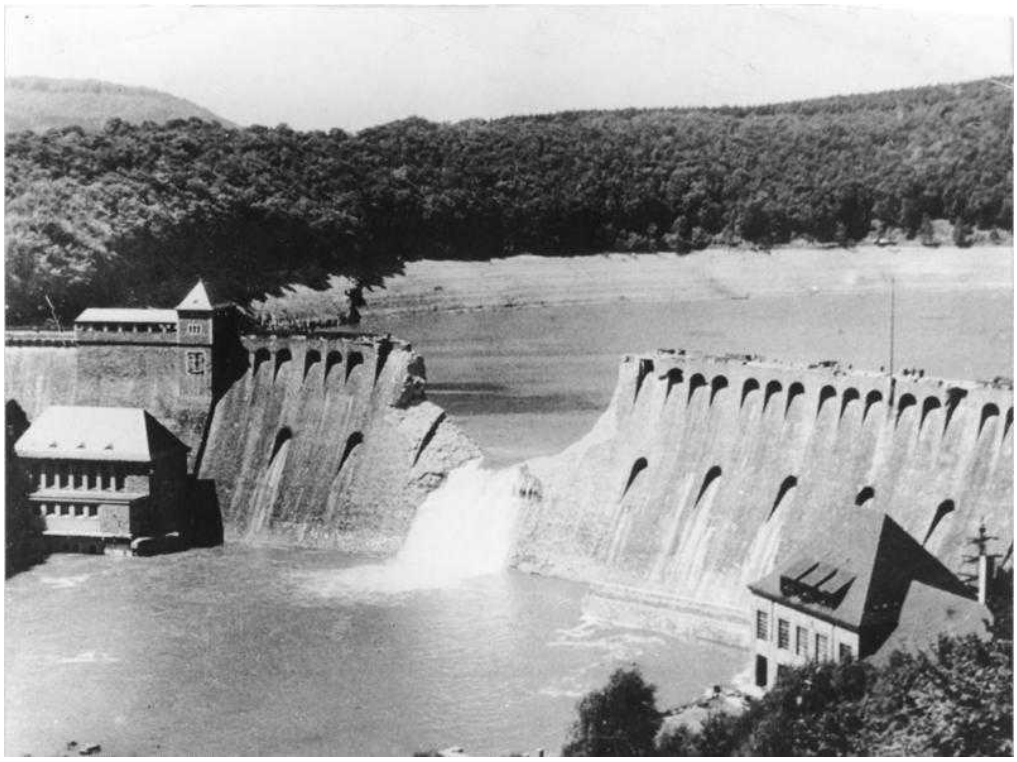
This was about 12 minutes flying time away. This journey was made without opposition, although in the moonlight identification of the dam itself proved initially quite difficult.



The approach to this target was even more difficult, dropping down past Waldeck Castle into a valley, flying towards the Hammerberg spit of land in the lake and then turning 90° left for a short run onto the dam face. The Lancasters started by circling into an anti-clockwise direction over Waldeck Castle and Shannon (AJ-Z) was given the task of the first attack.
AJ-L made three unsuccessful attempts to get the right position. Shannon was having problems achieving the required height and approach angle, so Gibson put him into a holding pattern and called Maudslay in AJ-L. He also had tremendous problems getting into position and Gibson ordered him to hold off. He put Shannon back onto the task and he made two further attempts before on the third he was able to drop the *Upkeep*. It bounced twice and exploded south of the dam without producing any visible result whatsoever.

Maudslay then came in again and he released his *Upkeep* during his second approach. He dropped his weapon slightly too late and it hit the crest of the dam and exploded with a brilliant flash lighting up the countryside for miles around. The explosion occurred right behind Maudslay's Lancaster, which had just crossed the crest of the dam, and Gibson tried to raise him on the VHF. Other crew members reported hearing a weak unnatural, almost dismembered voice in reply and at the time it was believed that Maudslay had crashed, his aircraft having been damaged by the blast. In practice, however he had struggled away with a damaged aircraft and started on the return journey, but he was shot down by light flak at 02:36 at Emmerich-Klein-Netterdn. Maudslay and all of his crew died.

AJ-N, piloted by Les Knight, was then ordered to make its approach with Gibson flying alongside to suppress the flak. The bomb bounced three times and struck the dam to the south of the centre and exploded. The blast visibly shook the whole dam and then the central wall collapsed, allowing thousands of cubic yards of water to roar through the breach.



The Second Wave

Four of the aircraft took off normally. However, Flight Lieutenant Joe McCarthy in AJ-Q was not able to take off. His pre-flight checks revealed a coolant leak in the number 4 engine and consequently the whole crew changed to one of the reserve aircraft AJ-T and suffered a 20 minute delay in doing so.

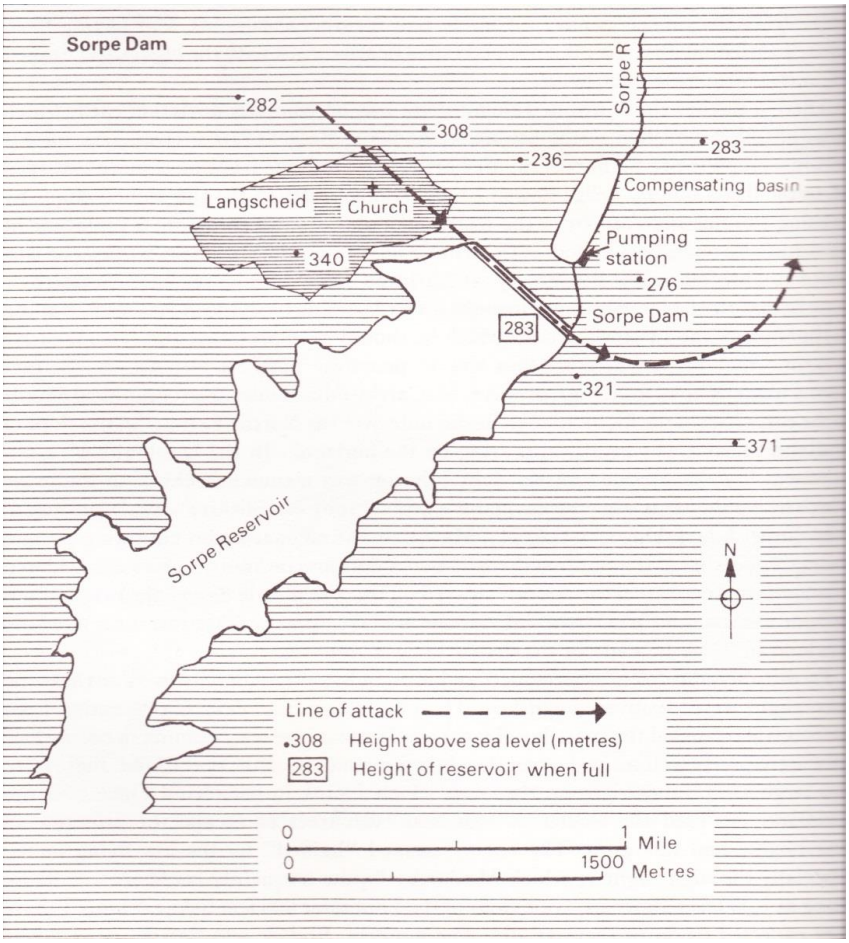
Byers (AJ-K) was slightly off course and flew over a heavily defended island. He was shot down by flak off the Dutch coast at 23:00). There were no survivors.

Barlow (AJ-E) crashed near Haldern, Germany at approx 23:58. Reports said that he hit power cables. The rear gun bay broke away and the gunner survived, albeit with a broken back.

Munro (AJ-W) was hit over the Dutch coast at 23:00 and aborted the mission as the intercom had been knocked out and there was also a hydraulic problem.

Rice (AJ-H) lost his *Upkeep* at 23:00 over the Dutch coast after clipping the sea while trying to avoid the flak. The rear gunner felt the effect of the near crash most keenly – after the bomb had been ripped out, a sheet of water shot down the fuselage towards him, picking up the contents of the Elsan before nearly drowning him! Rice aborted the mission and returned home.

McCarthy took off approximately 34 minutes later than the rest of the second wave. He attacked the Sorpe dam at 00:46. It was immediately apparent that the approach to the dam was extremely challenging, and so it proved.



McCarthy flew the approach nine times but found it difficult to clear the high hill and then bring the Lancaster down low enough, with the church steeple on the approach proving particularly troublesome, and either McCarthy himself or his bomb-aimer were not satisfied that all was right and called for the aircraft to go around again. The other members of the crew became restless as the bomber had now been circuiting the dam for half an hour and they were also puzzled that no other aircraft from the second wave had appeared. Eventually, on the tenth approach both McCarthy and his bomb-aimer were satisfied that the approach was perfect and dropped the bomb alongside the dam.
Two and a half hours later Brown, who had received a radio message directing his aircraft to attack the Sorpe while in the air, arrived at the dam and found that the ground mist was now even thicker. Brown found the approach no easier than McCarthy, and the thickening mist made flying the circuit correctly difficult even though the dam itself was clear, and after flying into a mist-bound nearby valley and nearly crashing he ordered that incendiaries be dropped round the circuit to help him.

In all Brown flew five separate approaches before dropping the mine on his sixth attempt. Although both mines exploded close to the dam and caused considerable damage, no breach occurred. The loss of so many from the second wave had seriously weakened the assault on the Sorpe and it survived the attack.

Third Wave

Ottley (AJ-C) was shot down over Hamm, Germany at approx 02:35. There was one survivor, Tees, who became a prisoner of war.
Burpee (AJ-S) was shot down over Gilze-Rijen airfield in Holland at approx 02:00 . There were no survivors.
Brown (AJ-F) attacked the Sorpe dam at 03:14 as described above.
Townsend (AJ-O) attacked the Ennepe dam at 03:41 but failed to breach it. AJ-O was the only aircraft to attack any of the secondary targets and was the last aircraft to return.
Anderson (AJ-Y) did not attack a target and returned with *Upkeep* intact.

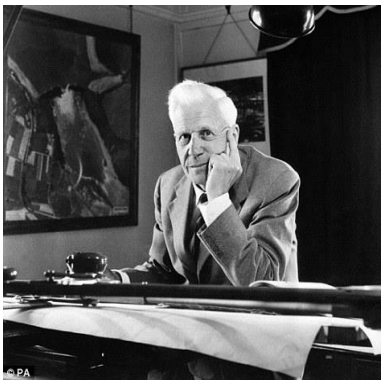
The 617 Squadron dams raid tally

19 aircraft took off to attack the dams:

- 3 turned back;
- 5 were lost before the attacks;
- 11 aircraft attacked the dams;
- 1 aircraft was lost during the attack;
- 2 aircraft were lost after the attack;
- 8 aircraft returned.

Decorations were awarded to 34 members of the air crew: Victoria Cross – 1; Distinguished Service Order – 5; Distinguished Flying Cross – 10; Bar to Distinguished Flying Cross – 4; Conspicuous Gallantry Medal – 2; Distinguished Flying Medal 11; Bar to Distinguished Flying Medal – 1.
53 air crew were killed in action.

Conclusion



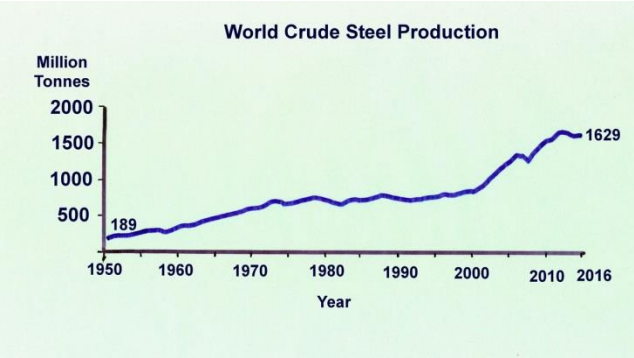
Barnes Wallis took the loss of life very badly. His daughter said that he never got over it and when, after the war, Wallis was given £10,000 as an 'Inventors Award', he would not accept it. He said: 'I will not touch the money, it is blood money.' He quoted some words of David from the Bible: 'Is not this the blood of the men who went in jeopardy of their lives'. However, he used the award to fund a bursary at his old school, Christ's Hospital, for the children of RAF personnel killed in service. Barnes Wallis continued to work at his desk into his 80s and died on 30th October 1979, at the age of 92.

In discussion, Dudley was asked if he thought the raid was worth it, given the high number of casualties. He said that it was, for a number of reasons: it cost the Germans about 6 months' production at a critical time; it diverted resources to rebuild the dams, who might otherwise have been working to strengthen defences in Normandy; there was a significant effect on British (and German) morale; and it also affected President Roosevelt. Finally, to paraphrase a remark by one of the 617 aircrew, if you weren't there, you aren't entitled to comment!
Our thanks to Dudley Hooley for another inspiring talk. This report makes extensive use of pictures and notes form his presentation, but it doesn't do full justice to the amazing detail that he had uncovered, or the way he presented it.
Perry Eastaugh
January 2018

Talk
Tuesday 9th January 2018 – "Steel – from Bessemer to today"
Dr Tim Smith B Tech, PhD, C Eng; MIM

The 21 Century Steel Industry

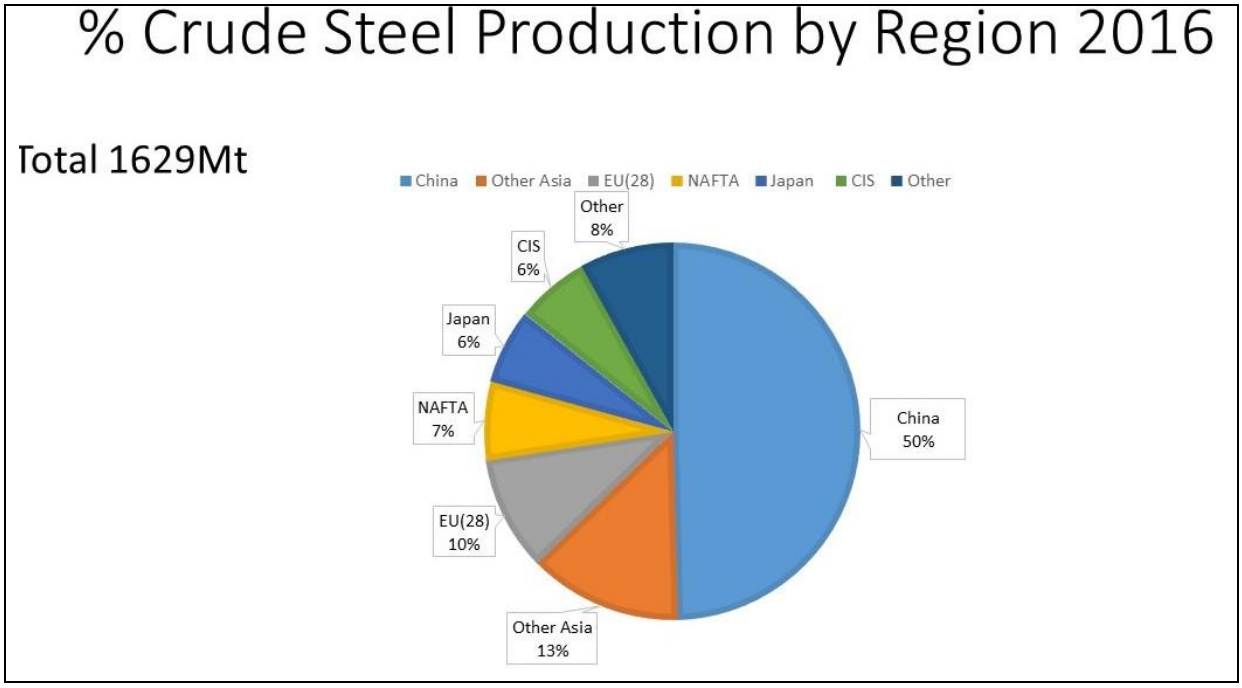
Worldwide production of crude steel reached 1629 million metric tonnes (Mt) in 2016 showing an average annual growth rate since 1950 of 11.5%. Steel output is second only to concrete as an engineering material.



China accounted for close to half of world steel output relying on western technology for quality steel production.

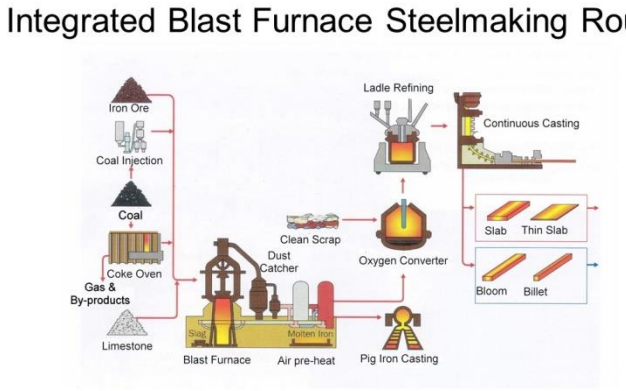
Iron Ore

Today, most steelmakers import high grade ore with an iron content of 62 – 65%. This contrasts with previously mined UK domestic ore – for example around Corby - of just 20-30% iron content. Corby ceased steel production in 1980 – but still makes tube products from bought-in steel – as, being inland, it cannot compete with plants located on the coast which enable ore imports by ship.
Australia is by far the largest producer of this high grade ore (811Mt in 2015) out of a world total of 2015Mt. Brazil is the second largest producer at 422Mt.
Europe produced just 39Mt of which Sweden supplied 24.6Mt or 63%. Worldwide, 1600Mt of ore was exported – 80% of world production. Nearly half of this went to China which also mines low grade domestic ore.



Ironmaking

Nearly three quarters of steel is produced using ore as the starting material. This is called the integrated route and produces a high quality steel.



Ore is fed to a blast furnace – close to 600 operating worldwide - with annual outputs ranging from 1 to 3Mt. The iron ore may be as lump ore but more commonly ore fines are mixed with coke fines and fired on a grate to produce sinter.

Concentrated ore fines may also be pelletized to about 1cm diameter balls for feed to the blast furnace. Coal converted to coke is the main furnace fuel but high grade pulverised coal is often additionally injected along with the blast of air to reduce coke consumption. In Germany and Austria, pelletised plastics are also injected to reduce CO_2 emissions. Limestone, which acts as a flux combining with gangue materials in preference to iron, is also charged. Air, preheated to 1000 ºC, and which may be enriched with oxygen by a few percent, provides the blast through an array of tuyeres located 2m or so above the base of the furnace.

The output of the blast furnace is molten iron containing about 4% carbon and molten slag which has a market for cement manufacture and road surfacing. Other by-products are a high calorific gas from the coke ovens and a lower value gas from the blast furnace. These are normally blended together and used on site to fire reheat furnaces and preheat the air blast. Dust is another product – but an undesired one - which requires capturing, pelletising or adding to the sinter line before returning to the furnace.

Most of the iron goes directly to steelmaking although a small proportion is cast into small ingots called ‘pigs’ for sale to foundries or if there is a delay for maintenance in the steelmaking shop.

Several new ironmaking processes have been developed in the past 30 years but the blast furnace remains the supreme producer accounting for 95.5% of world output. The most successful of these alternative methods is the production of direct reduced iron which accounted for 64.2Mt in 2016 or 3.6% of world output. In this process, the iron is in a solid state and is generally charged to an electric arc furnace for melting. Most direct reduced iron is made by reforming natural gas to hydrogen which gives it a much lower carbon footprint than the blast furnace. The lowering of CO_2

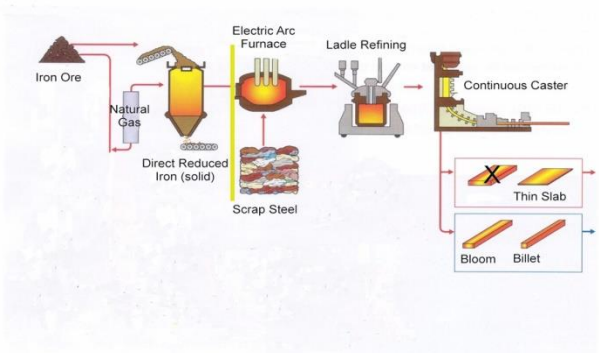
emissions is a key reason for producing direct reduced iron, the other being a good feed to electric furnaces. Other processes in use to reduce CO_2 emissions are Corex which effectively combines a shaft furnace producing direct reduced iron and a melter gasifier to give a molten metal similar to blast furnace metal and Finex which is a modification of Corex able to partly charge ore fines which are a lower cost input, and dust. Prototype methods presently under trial to reduce CO_2 emissions are HIsarna which combines a cyclone converter ore pre reducer with a melter – reducer and the recirculation of the top gas from the blast furnace back to the tuyeres once the CO_2 has been removed. With carbon capture and storage this reduces CO_2 emissions by 60%.

Steelmaking

Nearly three quarters of steel is made in the oxygen converter. Molten iron is charged to a refractory lined tiltable vessel– known as the basic oxygen converter (also referred to as the BOF or LD converter). Here the carbon content is reduced to around 0.05% by blowing pure oxygen at supersonic speed into the melt via a top lance. 10-20% of clean scrap is added as a coolant during this very exothermic reaction. The term 'Basic' refers to the ability of the converter to refine high phosphorus metal by the addition of limestone. High phosphorus metal requires an intermediate tapping of the slag which contains most of the phosphorus. After about 20 minutes the converter is tipped to tap the metal into a refractory lined ladle – typically capable of holding 100t or more. Deoxidants – silicon or aluminium – are added at this stage to remove excess gas. The ladle is transported to a ladle station where final refining of the metal and any alloying additions are made.

The alternative common way of making steel is in the electric arc furnace. Here, scrap metal is melted under an arc often with the assistance of oxy-fuel burners.

Electric Arc Furnace (EAF) Steelmaking Route



Direct reduced iron or solid pig iron may be added to 'dilute' impurities – such as copper – trapped in the scrap. The electric arc furnace effectively recovers post-use steel and provides a carbon footprint of only one-quarter that of the blast furnace – basic oxygen converter route.

The blast furnace-basic oxygen converter integrated route produces a superior quality steel compared to the electric arc furnace which can be rolled to flat products such as strip for use in such markets as automotive, white goods and plate products. As well as flat products the blast furnace-basic oxygen converter route produces long products such as rails for railways and heavy beams for construction.

The electric arc furnace route generally produces long products such as re-bar, angles and bar but in recent year some electric arc furnace operators have entered the more lucrative flats markets by casting 25-20mm 'thin' slabs to feed a linked rolling mill with only half the number of mill stands as a conventional mill thus saving capital and operating costs. Electric arc furnace steel is refined at the ladle station in a similar manner to basic oxygen converter steel.

While the electric arc furnace generally produces a lower grade steel than the basic oxygen converter - it is a much more flexible route as power can be turned on or off to meet market demand. It takes weeks to slow down basic oxygen converter production as it is supplied by the blast furnace which has a continuous output and can only be slowed by about 20% without shutting it down completely, this taking many weeks to achieve and later re-start.

Continuous Casting

Once refining is complete, the ladle is moved to the continuous caster consisting of one or more water cooled bottomless copper moulds set vertically. The steel is teemed (poured) at a steady rate into the mould where a shell of metal forms enabling the strand to be slowly drawn out of the bottom of the mould supported by rollers and curved through 90 degrees to the horizontal. The mould oscillates vertically by a few centimetres and a powder or liquid lubricant is added to reduce sticking between the mould and solidifying shell which may otherwise rupture. Once fully solidified, the hot strand is cut to length using an oxygen burner. The cast strand may be in slab form – typically 250mm thick and 1.5 to 2m wide - for rolling to strip, or of square or round cross section bloom or billet – the latter having a smaller cross-

section. These are rolled to long products such as bar, angles or beams or tube. An uninterrupted supply of steel is assured to the caster by mounting the ladle on a rotating turret enabling an empty ladle to be replaced with a full one without interrupting supply as the caster is fed via an intermediate chamber (tundish) holding 10-20t of metal which both ensures a constant head of metal to the mould and acts as a reservoir during exchanging ladles. Even different grades of steel can be supplied to the caster in this way with the transition part of the cast strand being discarded and returned for remelting.

Processing

The semi-products from the caster are hot rolled to reduce the dimensions. A reheat to about 1000 ºC is required prior to rolling, energy being conserved if the semis can be charged to the reheat furnace while still hot from casting.
Long products are rolled to their final dimensions while still hot. Flat products may undergo a further reduction by cold rolling. If this is the case, oxide scale formed during hot rolling is first removed by acid pickling. The cold rolled strip requires annealing to soften it after cold rolling. If a coating is to be added such as zinc the process may take place in a continuous annealing and galvanising line where the zinc is added by passing the annealed strip through a bath of molten zinc, the thickness of which is controlled by an air-knife on exiting the bath. An organic coating (paint) may be added at a subsequent stage by dipping and curing. Other metal coatings such as tinplate are normally achieved by electro-deposition.
Finally, the strip may be cut to length and / or cut into narrower strips as the customer requires. Much of this processing work is carried out by Service Centres some of which are owned by the mills.

Sustainability

The energy to produce a tonne of steel has fallen 39% from 29.4GJ in 1960 to 18GJ in 2005. Between 1970 and today the fall has increased to 50%. For rolled products, it has fallen 50% from 44.9GJ/t to 22.3GJ/t. Ore inputs have dropped 14% from 1.591t to 1.360t.
Average CO_2 emissions from an integrated (blast furnace – basic oxygen converter) steelmaker in 2010 were $1.88CO_2$eq/t hot metal. For an electric arc furnace steelmaker using only scrap, emissions were $455kgCO_2$eq/t – i.e. 76% less. These figures compare favourably with the production of primary aluminium which averages $10tCO_2$eq/t aluminium.

UK steel

UK has some 200 Stockholders and Service Centres. Six sites make molten steel, two are integrated blast furnace – basic oxygen converter sites and four are electric arc furnace sites. In 2016, 7.6Mt of crude steel were made in UK. The total value of steel production and processing was £1.2bn and 50% of output was exported – 70% of exports going to the EU. The workforce directly employed in steel manufacture is 31399 but four times this number are dependent on the industry – such as sub-contractors – making the total employed close to 156500.
For more information on the world steel industry visit www.worldsteel.org

Talk
Tuesday 13th February 2018 – "Bring Energy to Lfe – Electricity System Operator"
Dr. Tianyu Luo, National Grid ENCC.

Tianyu started by explaining the role of the National Grid: it manages the supply of electricity between the generators and the distributors across Great Britain. Transmission Owners (TO) are responsible for owning, building and maintaining the assets; they include Scottish and Southern Energy, Scottish Power, and various Offshore Transmission Owners. The System Operator (SO) is responsible for:

- Balancing the GB system;
- Configuring the GB Transmission System;
- Operational planning;
- Connection and use of System Agreements with generators, suppliers and distribution companies;
- GB charging and billing.

Currently National Grid has both TO and SO roles; these are in the process of being separated. A TO/SO code is used to define interfaces such as outage planning and investment decisions.

Electricity Markets

There are two main categories:

- The Forwards and Futures Market allows electricity contracts to be struck over timescales ranging from several years to c. 24 hours ahead of real time;
- The Power Exchanges allow parties to fine tune their positions from 24 hours out until 1 hour before actual delivery.

Suppliers contract with Generators through forward markets, and Generators decide which units to run to meet their contractual obligations. Suppliers forecast electricity requirements per half hour, and arrange contracts with generators per half hour. However, as the graph illustrates, life is rarely as forecast, so we need a mechanism to facilitate real time balancing.

Real Time Operation

The System Operator has two key roles:

- Managing electricity flows across the networks (System)
- Balancing the generation with demand (Energy)

These operations are subject to security and quality of supply standards, which state that there shall not be:

- A loss of supply;
- A permanent change in frequency below 49.5Hz or above 50.5Hz;
- *Unacceptable* high or low voltage conditions;
- *Unacceptable* overloading of transmission apparatus;
- System instability.

Since energy cannot easily be stored (in useful quantities), actual demand must equal actual generation on a second by second basis, so there is a Balancing Mechanism. This operates from one hour ahead of real time and enables the National Grid to pay generators/ suppliers to change their output to:

- Achieve real time energy balance;
- Ensure that there are sufficient reserves available;
- Respond following generator breakdowns;
- Manage system constraints.

Some facts and figures about the Balancing Mechanism: typically, it handles some 3% of all energy. 1,000 generation/ demand units submit data and every half hour the BM receives c. 11,000 data items. It issues c. 20 balancing actions each half hour (or 360,000 p.a.) and processes some 1bn items a year. The BM has a cash flow in excess of £1bn and the cost of operating the Power system is >£500M.

Control Room Operations

There are three active control rooms with 6 shift teams and 25 people per shift. There are two Energy National Control Centres (one a backup) in the Wokingham area, together with the Transmission Network Control Centre at Warwick. The management structure divides the teams into 3 groups: Strategy, Energy Balancing, and Transmission.

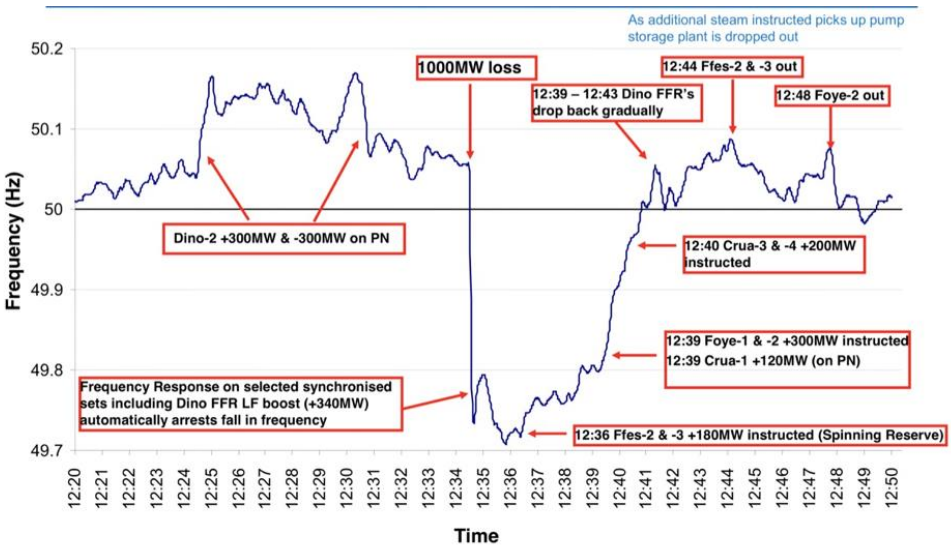
Real Time Balancing – keeping the frequency at 50Hz

If supply and demand are not kept in balance, the frequency is affected with the following impacts:

52.0 Generators tripping
50.5 Upper statutory limit
50.0 Normal operating frequency
49.5 Lower statutory limit
48.8 Demand disconnection starts
47.8 Demand disconnection complete

Pumped hydro storage can be used to boost the supply for a short time while other generators are brought on line. The UK has four pumped storage projects, the biggest being Dinorwig. The following table gives brief details of each:

Project	Year of Commissioning	Capacity (MW)
Dinorwig	1984	1,728
Foyers	1975	305
Cruachan	1965	440
Ffestiniog	1963	360

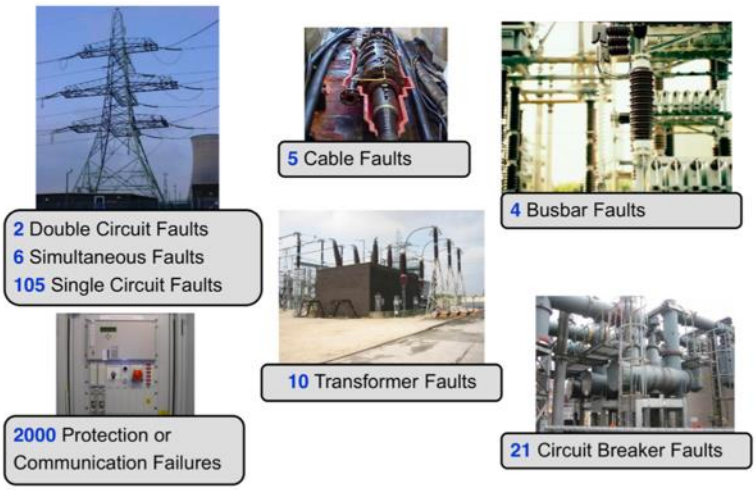


The graph opposite shows how they are used to compensate for the sudden loss of 1,000MW on a Bipole.

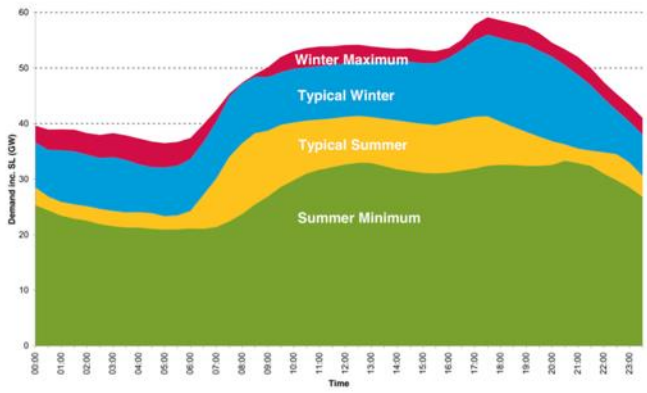
Managing Uncertainty

A number of things can go wrong within the transmission system.

This diagram shows how faults typically break down into different categories:



Demand Forecasting



When trying to forecast likely demand, the National Grid uses information from many sources, including the Met Office, NG weather stations, TV guides, and relevant news and events. The seasons and time of day also have a significant impact on demand as this chart shows:

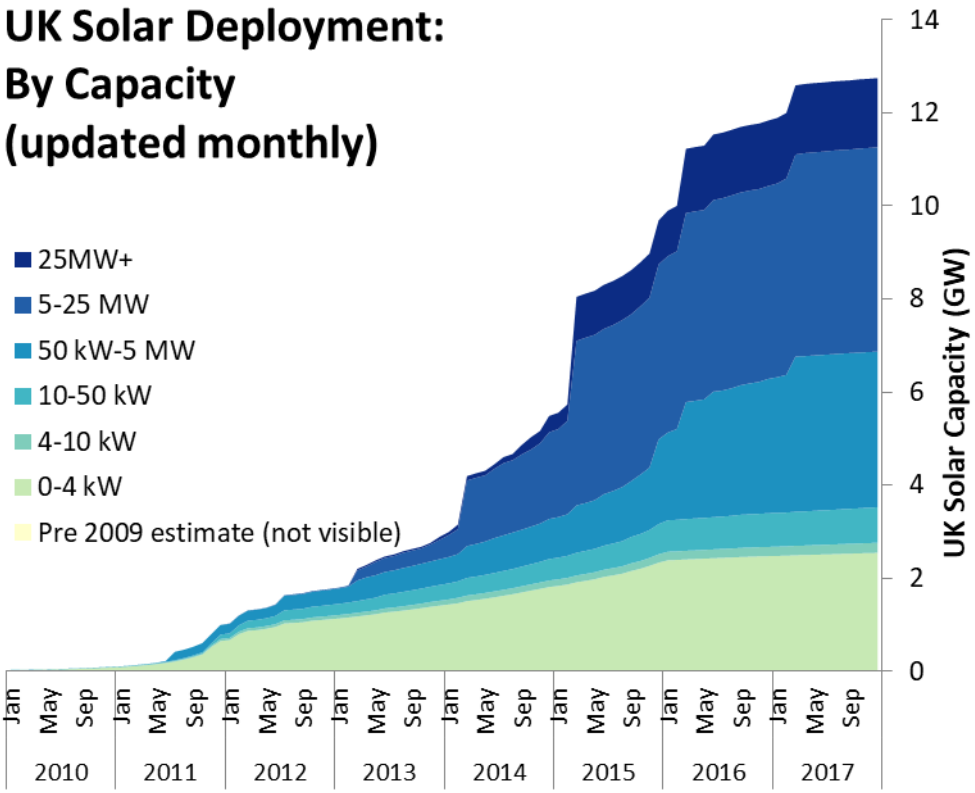
Electricity demand is highest in very cold weather, reduces in mild weather, but then increases again in very hot weather. Similarly, the level of lighting has an effect, with power demand on bright days being significantly less than on dull ones. Equally, at low temperatures (below about 10^{o}C), higher wind speeds tend to increase demand. Here is an indication of the impact of weather conditions nationally:

- Temperature: 1^{o}C fall in cold conditions: +500MW
- Cloud cover: clear sky to thick cloud: +1,500MW
- Precipitation: no rain to heavy rain: +1,000MW

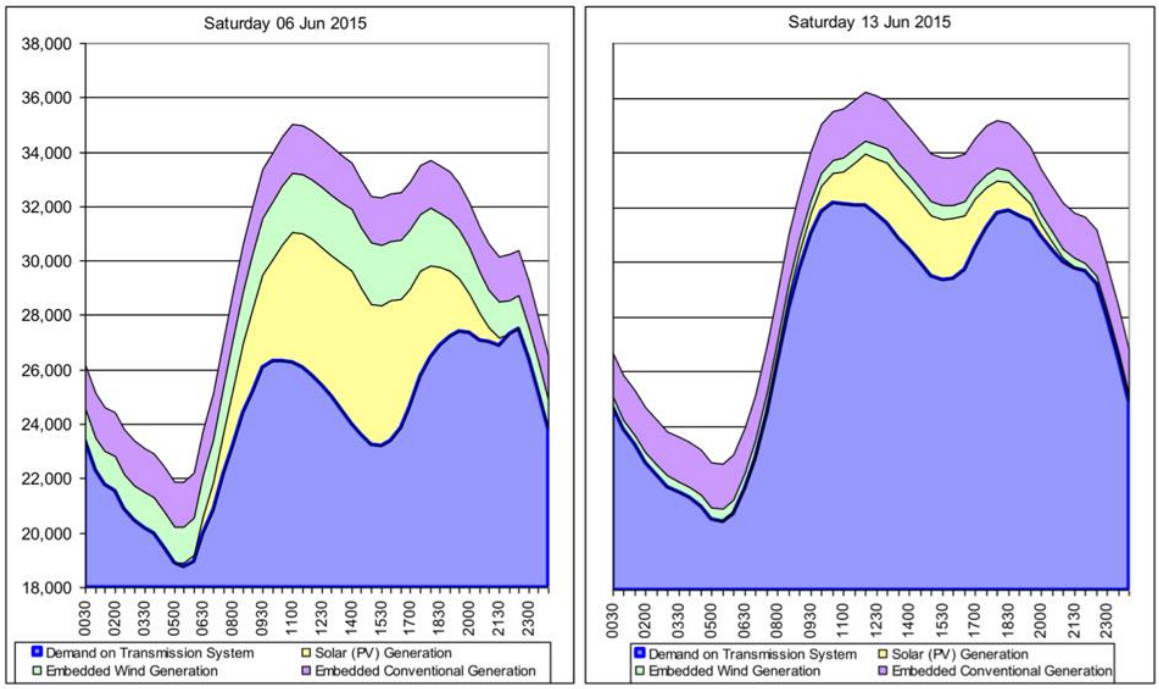
- Temperature: 1°C rise in hot conditions: +500MW
- Wind chill: 10mph rise in cold conditions: +1,000MW

The impact of renewable energy

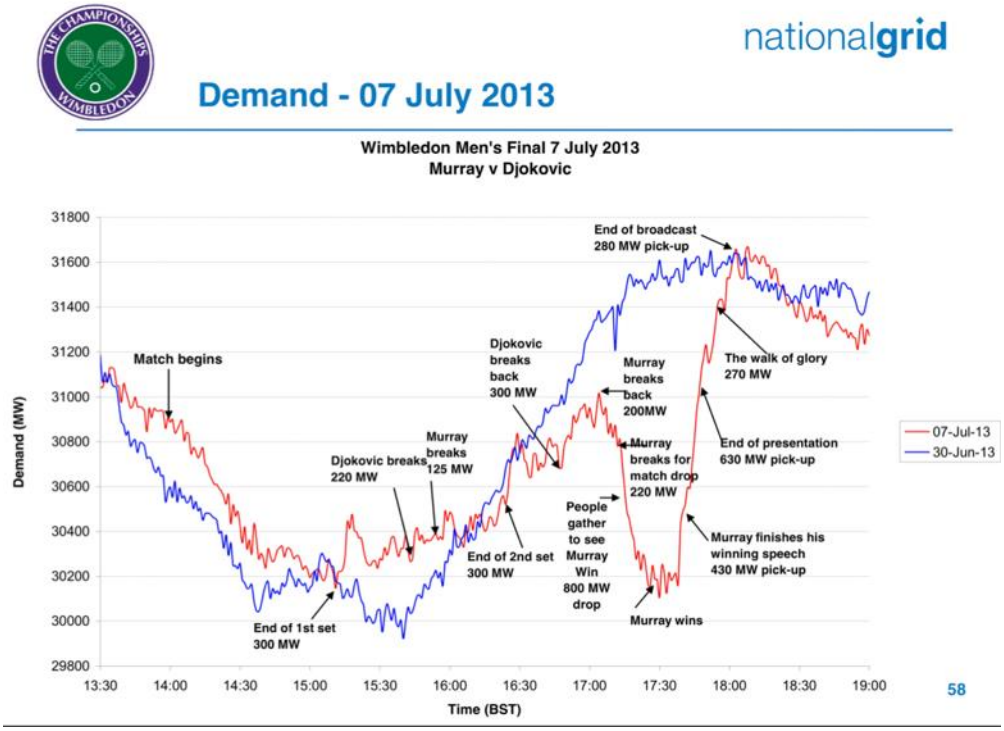
UK photovoltaic (PV) capacity has grown significantly over the past few years and, by the end of 2017, stood at 12.75MW. Wind turbines have a total capacity of c. 18,500MW – from some 7,000 onshore turbines and 1660 offshore turbines.



The following charts show the impact of weather on the way in which power is generated. Saturday 6th June 2015 was a sunny, windy day, while Saturday 13th June was overcast and still. You can see that during the daytime, PV and wind generation provided a substantial contribution on 6th June, but a much smaller one the following Saturday.



The impact of events on demand



The effect of television programmes on power demand is well documented, but the graph opposite comparing demand on the day of the Wimbledon Men's Final in July 2013 with the previous Sunday gives a dramatic example.

Other examples of TV Pickup (ie the increase in demand at programme break points) are shown in the following table:

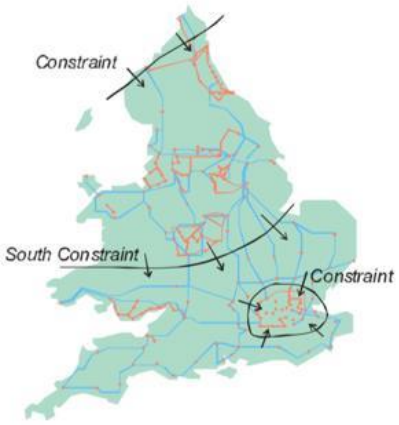
Year	Date	Programme	Pickup (MW)
1990	4 July	World Cup Semi-final: W Germany vs England	2800
2002	21 June	World Cup: England vs Brazil half time	2570
2011	29 April	Royal Wedding	2300
2001	5 April	Eastenders – Who shot Phil Mitchell	2300
2003	22 Nov	Rugby World Cup: Final England vs Australia half time	2110
1998	30 June	World Cup: England vs Argentina half time	2100
2006	1 July	World Cup: England vs Portugal end	1960
2006	20 June	World Cup: England vs Sweden half time	1830
1999	21 April	Champions' League Semi-final: Juventus vs Man U half time	1820

System Constraints

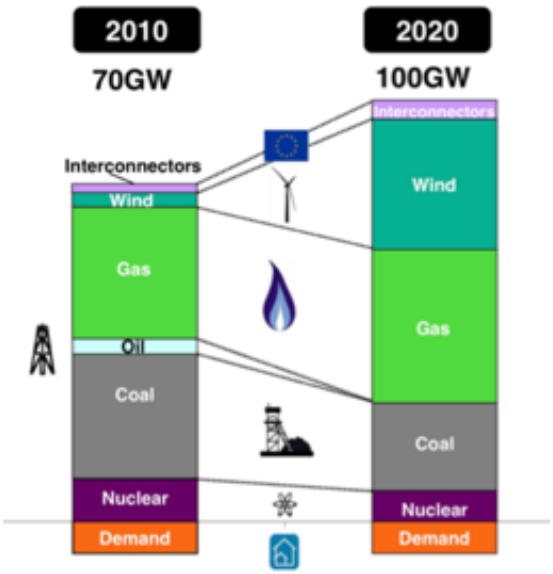
The system is not geographically balanced for generation and demand. Bottlenecks arise that require power flows to be 'constrained'.

Limiting factors may be:

- Thermal (line loading)
- System voltages
- Stability of generators
- Fault levels
- Reserve requirements

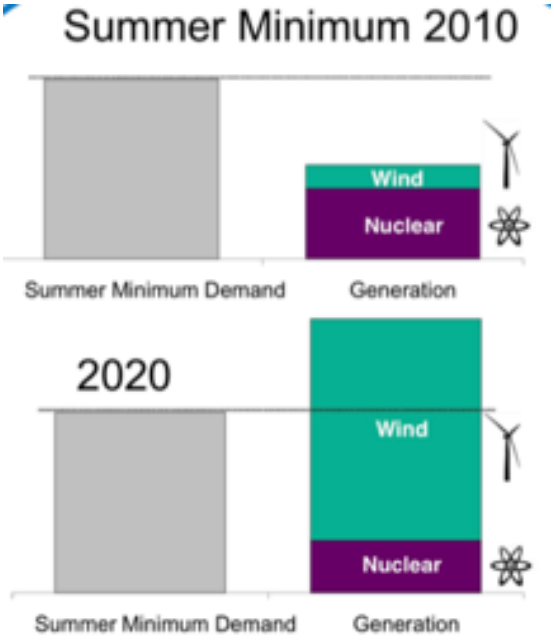


The Future

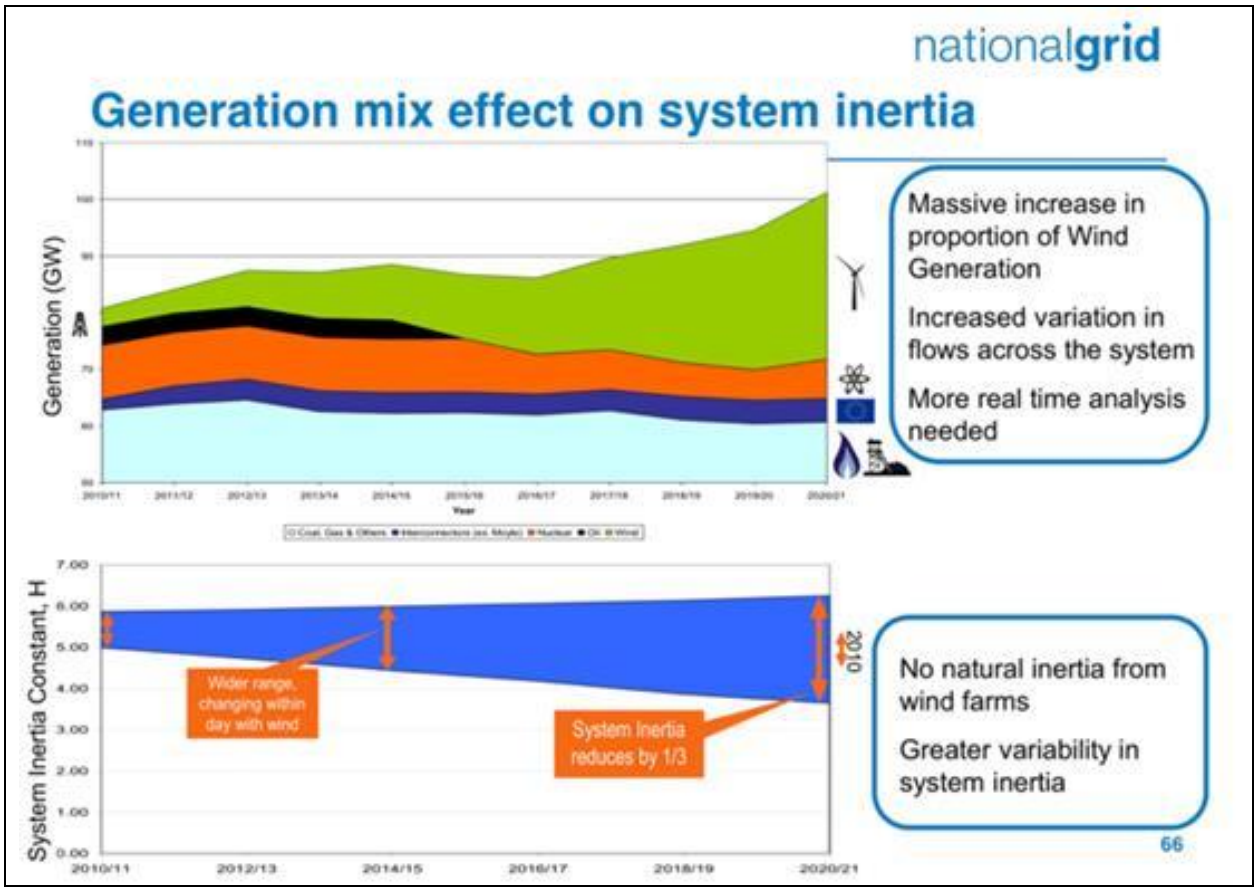


The UK is committed to reducing CO_2 emissions to 80% below 1990 levels by 2050. Scotland has an additional target of deriving 50% of gross electricity consumption from renewable resources by 2020. Because of the variability of renewable generating capability, there will be a greater reliance on gas for balancing. The changing mix will also lead to a high level of generating capacity, some with very low utilisation, which affects the economics.

Increasing the availability of wind power generation leads to situations where high winds will cause the capacity to exceed demand when demand levels are low. When this occurs, we either have to have more interconnectors so that we can export power from the UK, more storage schemes that can us the excess capacity, or constrain the generators to switch off their wind turbines.



Increasing the proportion of electricity derived from wind turbines will reduce the inertia in the system, as shown in the charts below. This is important because the inertia inherent in the turbine systems used for fossil fuel-based power generation reduce the effect of mismatches between supply and demand on grid frequency. However, the technology exists to introduce 'synthetic inertia' into the system to protect the grid.



Decarbonisation, decentralisation, new technologies and business models are driving the transition to a multi-directional interactive system; electricity industry arrangements need to evolve to facilitate transition to the new model.

In conclusion, Tianyu said that those who would like to understand a bit more about plans for the future could find two interactive documents on the National Grid website. These were *Future Energy Scenarios* and, for those with less time, *Future Energy Scenarios in 5 Minutes.* Both were published in July 2017. The web link is http://fes.nationalgrid.com/fes-document/

Perry Eastaugh

Talk
Tuesday 13th March 2018 – "Across India by Train"

Colin Boocock

The purpose of the talk was to reminisce about journeys Colin had made with his wife across India visiting such places as Delhi, Kolkata and the narrow gauge railway lines to the Hill Stations of Shimla and Darjeeling.

Colin is a passionate, long-serving member of the charity The Railway Children, which provides dedicated support to the thousands of street children all over India but, in particular, those in the large metropolises of Mumbai, Delhi, Chennai and Kolkata. Colin travelled from where he lives in Derby, only asking for a donation to his favoured charity, which we were pleased to comply with.

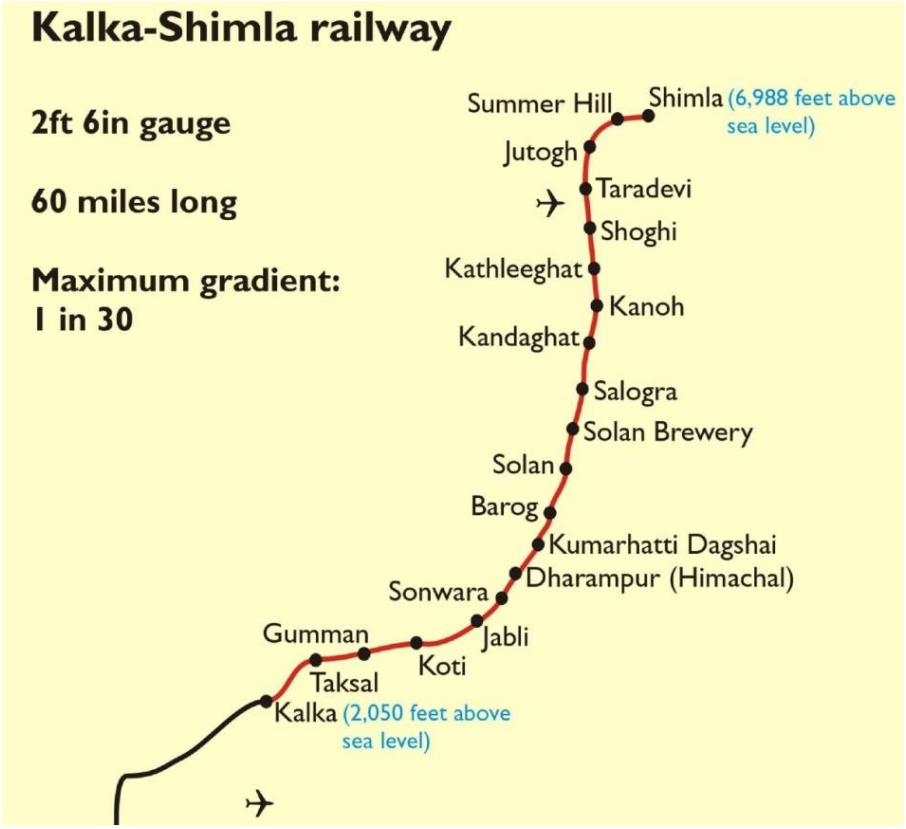
His talk was laced with his experiences and the showing of over one hundred of his own colour slides.

We have added a representative sample of these in this summary of his talk so that members are able to appreciate some of his wonderful experiences.

Members can of course also read this talk on our website and enjoy the associated pictures in full colour.

One should add that Colin is a prolific author and members can find details of his literary output on the usual websites including Pen and Sword.

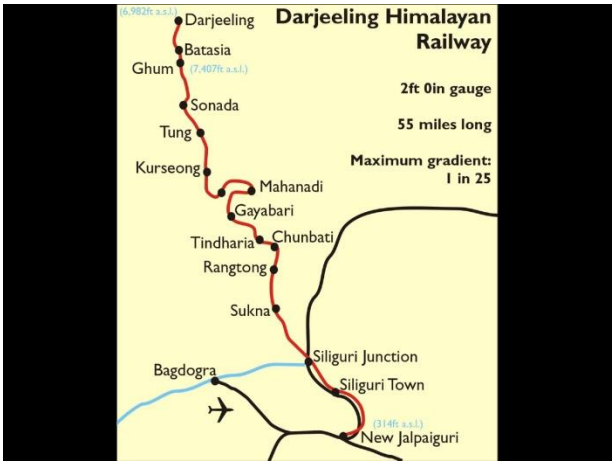
The trip covered routes from Delhi (broad gauge) via Kalka to Shimla (narrow gauge), then to Agra (for the Taj), and onward to Siliguri for the Darjeeling UNESCO World Heritage railway of 55 miles in length which took 17 years to build.



Shimla is on a hill, which is why it is referred to as a hill station. Some of the structures on the hillside look pretty precarious. Nevertheless this is where the wealthy went to escape the heat, smell and pollution of the cities.

Back on the main line, old colonial habits die hard as the porters in their red robes still carry huge weights on their head.

The journey took in the Taj Mahal at Agra



A map of the 55 mile long Darjeeling Line from Siliguri to Darjeeling

Our charter was steam- hauled by a very old Sharp Stewart steam loco, seen here being watered and serviced at the first station out of Siliguri.

A roadside sign extolling the virtues of an independent Gorkaland - the locals resent all the tourist money going to Kolkata (West Bengal) when to this day water has to be taken in by road as there is no mains system in Darjeeling!

Passing the Batasia loop and memorial to the fallen Gurkhas.

The railways are in a fragile state as repairs are always just around the corner and always unexpected!

The river still carries strange types of traffic. A fitting end to an incredible journey.

End of Newsletter

REPLY SLIP - SPRING LUNCH

To: George Woollard, 18 St Lawrence Ave, Worthing West Sussex BN14 7JF (01903 523640)

Email : Georgewoollard1@hotmail.co.uk

Can you please reserve me …….. places for the Spring Lunch at Northbrook Collage, Worthing on ***Wednesday 18th April 2018.*** 12.00 for 12.30.

Full name:……(Block capitals)

Address………

……

……

Telephone Number…….Name of guest/s …….

E mail address……

I enclose a cheque made payable to RCEA for **£…….(£15.00) per person**

(Separate cheque for this event please)

Applications by Sunday 1st April

If possible, I would like to be seated with……..

REPLY SLIP - AMEX STADIUM TOUR

To: George Woollard, 18 St Lawrence Ave, Worthing West Sussex BN14 7JF (01903 523640)

Email : Georgewoollard1@hotmail.co.uk

Can you please reserve me …….. places for the visit to the AMEX Stadium on Tuesday 24th April 2018

Full name:……(Block capitals)

Address………

……

……

Telephone Number…….Name of guest/s …….

E mail address……

I enclose a cheque made payable to RCEA for **£…….(£6.00) per person**

(Separate cheque for this event please)

Applications by Monday 16th April

REPLY SLIP – THREE BRIDGES MAINTENANCE FACILITY

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD
(01903 788858) Email perry.eastaugh@icloud.com

Please reserve me …… places to visit the Three Bridges Maintenance Facility on Thursday 7th June at 11.45am (time subject to confirmation hen we know summer train times to Three Bridges).
Full name: ……. (block capitals)

Address:…….

…….

Telephone number: ……..

Email address: ……..

Safety shoes must be worn. Please give your shoe size(s) if you need to borrow some:

……

Places are limited to a maximum of 20 visitors. Priority will be given to RCEA members.

Applications by Friday 18th May.

REPLY SLIP – VOLK'S ELECTRIC RAILWAY

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD
(01903 788858) Email perry.eastaugh@icloud.com

Please reserve me …… places to visit the Volk's Electric Railway on Thursday 5th July at 2pm.

Full name: ……. (block capitals)

Address:…….

…….

Telephone number: ……..

Email address: ……..

I enclose a cheque made payable to RCEA for **£.....(£15.00) per person**.

(Separate cheque for this event please).

Places are limited to a maximum of 20 visitors. Priority will be given to RCEA members and spouses.

Applications by Thursday 31st May.

REPLY SLIP- CNH Tractor Plant Basildon

To: Ivan Farrow, 14, Ring Road, Lancing, W Sussex BN15 0QF
Email: ivan_farrow @yahoo.com

I would like to attend the visit to CNH Tractor Plant on Tuesday 17th July 2018. Please reserve me a place.
RCEA member …….. Guest …….

Full name:.....(Block capitals)
Address..... .....
..... Telephone Number..... Email address.....

Name of guest……..

I enclose a cheque made payable to RCEA for £…….(£7.00) per person (Separate cheque for this event please)

REPLY SLIP – NATIONAL GRID ENCC

To: Perry Eastaugh, 33 Ruston Park, Rustington, Littlehampton, BN16 2AD (01903 788858) Email perry.eastaugh@icloud.com

Please provisionally reserve me …… places to visit the National Grid ENCC near Wokingham at a date to be confirmed (likely to be late September/ early October).

Full name: ……. (block capitals)

Address:…….

…….

Telephone number: ……..

Email address: ……..

Places are likely to be limited to a maximum of 20 visitors. Priority will be given to RCEA members. Once you have expressed an interest in this visit, Perry will be in contact to agree a suitable date and time.