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Cover Images:

Front: Mount Morgan mine, Queensland, circa 1908. Rail-mounted Whitaker Steam Excavator, in a difficult position, mining out old stopes from former underground workings. What is the purpose of the Hunslett locomotive, sans wagons? Discussion of this work is on page 14.
Photo: Seale Collection, CQU.

Back: Two photographs taken only 8-months apart during construction of the 7-track railway bridge over Eddy Avenue in Sydney. Notably, the clock in Central Station tower shows an almost identical time in both photos. Also see the story of the bridge from page 20.
Photos: from the Railway Resource Centre, Australian Railway Historical Society, NSW.

CONTENTS

Editorial

Again – no images in the editorial, but a remarkable trove in the stories that follow. EHA National Chair Neil Hogg gives us food for thought with his images of the wasted opportunities for regeneration and re-use on the famous Bethlehem Steel site in Pennsylvania, USA.

Mining Engineer and PhD, Ray Boyle, spent his working life at Mount Morgan, working his way up from apprentice fitter and turner with Mount Morgan Ltd. to Chief Engineer, before retiring in the 1980s. He was responsible for the Company donating its archives to Central Queensland University, from which collection he has mined the superb collection of historic photos that adorn his story.

Owen Peake, electrical engineer, has favoured us with another of his traveller's tales. He even managed to find another manhole cover in Hanoi, Vietnam.

And last, but definitely not least, is a tale of the building of the 7-track railway bridge over Eddy Avenue in Sydney, part of Bradfield's designs for the City Railway. Bill Phippen, OAM, FIEAust, and Manager of the ARHS Railway Resource Centre, is the custodian of a remarkable collection of archives and historic photos of the NSW Railways. The photos he has chosen to illustrate his story of the Eddy Avenue bridge are a source of endless fascination, showing life in Sydney in the 1920s. Through those photos, Phippen draws us to see the cleverness of Bradfield's design, in disguising a revolutionary cantilevered and reinforced concrete bridge as a simple series of conventional masonry arches. Nothing there to frighten the horses!

Recognition of Chaffey Bros. Irrigation Works in Australia

The American Society of Civil Engineers joins EHA at Psyche Bend.

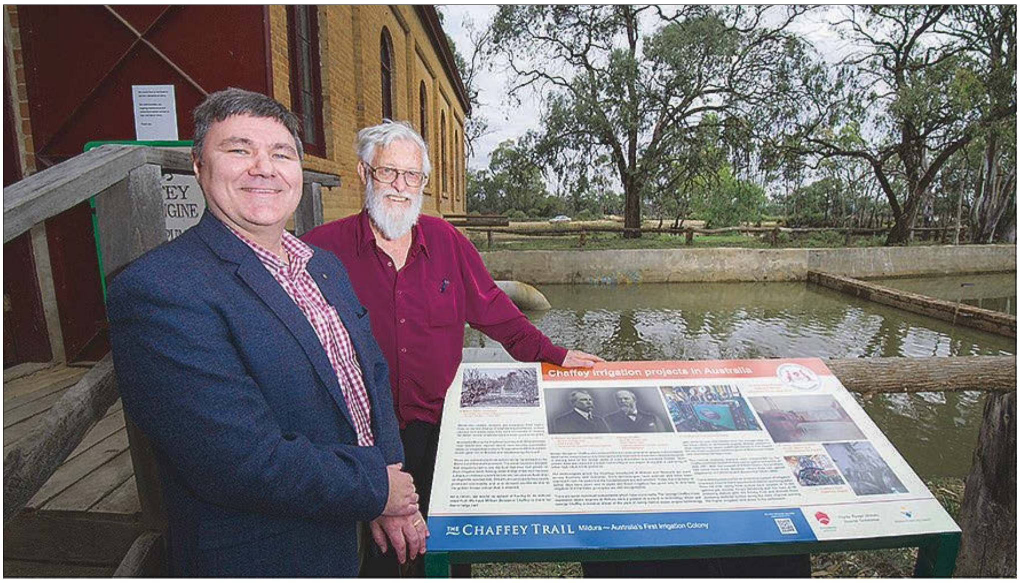
One of the events at the Mildura Engineering Heritage Conference, which ran from 9-13 October 2017, was a heritage recognition ceremony for the Chaffey Irrigation Works in Australia. This was held just before the final barbeque dinner at Psyche Bend Pumping Station.

EHA had long planned to recognise the Chaffey Irrigation Works as a part of the conference. EHA also nominated the site, under very similar terms to the EHA nomination, to the American Society of Civil Engineers (ASCE) for one of their International Historic Civil Engineering Landmark (IHCEL) awards. This nomination was successful and ASCE moved very quickly to enable a "double barrel" recognition ceremony with the ASCE Landmark and an EHA Engineering Heritage National Marker.

There are now five sites in Australia with IHCEL's: – Sydney Harbour Bridge; Snowy Mountains Hydro-electric Scheme; Goldfields Water Supply Scheme Western Australia; Gladesville Bridge, Sydney; and now the Chaffey Irrigation Works.

ASCE sent two representatives to the joint ceremony in Mildura. April Lander, who is Governor of ASCE Region 10 and works out of New Zealand, attended accompanied by Stuart Rothwell, President, ASCE - Australian Section.

Stuart Rothwell and April Lander unveil the ASCE Chaffey Brothers Irrigation Works Landmark plaque, fixed to the Psyche Bend Steam Pumping Engine House. Image: Owen Peake.



Guy Hodgkinson (left) and Owen Peake (right) with the EHA Interpretation Panel for the "Chaffey Irrigation Projects in Australia". This has been fixed outside the Pysche Bend Pumphouse. Image: Sunraysia Daily.

133 people attended the heritage recognition ceremony. Engineers Australia Regional stalwart David Eltringham was MC for the event while speakers included the two ASCE representatives, Guy Hodgkinson representing Victoria Division of Engineers Australia, and Mildura Councillor Mark Eckel who is also Chair of the Psyche Bend Historical Reserve Committee. The ASCE bronze plaque was unveiled on the wall of the Psyche Bend pumping station while the EHA interpretation is mounted on a steel stand nearby, incorporating a design which fits within the Mildura Rural City Council's Chaffey Trail concept.

Left: Steam pumping engine at Psyche Bend. Image: Heritage Victoria.

After the sunset ceremony everyone had the opportunity to marvel at the mighty Psyche Bend steam pumping engine leisurely pumping water from the Murray River into Kings Billabong. We then enjoyed a substantial barbeque put on by the local Rotary Club.

Owen Peake
Engineering Heritage Australia

Find the EHA Nomination Document at:
https://www.engineersaustralia.org.au/portal/system/files/engineering-heritage-australia/nomination-title/Chaffey%20Irrigation.Nomination.V5.Aug%202017.pdf

Engineering and Industrial Heritage in USA

From the Chair — A learning experience for Neil Hogg.

Overall impressions

During late August and September 2017 my wife and I visited the north-east of the US to explore this part of the country. We "just happened to be passing" quite a few engineering and technology sites so it was convenient to call in and have a look. I have not attempted a travelogue. I have used some examples to illustrate some things that made an impression on me.

I would say that the US faces the same problems we do in Australia, but because it's America, everything is bigger and there's more of it!

Buildings and Structures

As in Australia, preservation of built heritage is more widespread than movable heritage.

In New York City, the Empire State Building "Experience" included a very good display of photos and documents of the engineering and construction of the building. There was even an example of the 1930 era project planning Gantt charts used to manage the erection of the building in 18 months (one floor every 5 days).

A link between the engineering of the past and the engineering of today was an interactive display explaining how the building is being upgraded and why this is better than demolishing and building a new building.

Image right: Part of the display at the Empire State Building
Why retrofitting matters.

Movable Heritage

I found that museums are generally well funded, well supported by volunteers and, from what I experienced, well patronised by local visitors and tourists.

Image above: Experimental Aircraft Association Museum (Oshkosh, Wisconsin). A "private" museum funded by members and donors.

Image above: Udvar-Hazy Center (an annex of the Smithsonian Air & Space Museum). The building next door housed a space shuttle and space items.

Image right: National Museum of Industrial Heritage (Bethlehem, Pennsylvania), a community museum in a former industrial building, affiliated with Smithsonian, and mostly dependent on local funding and volunteers.
("National" doesn't mean it's the national museum).

Engineering and Industrial Heritage in USA

As in Australia, most exhibits in institutional museums are of the "natural history type" – stuffed and in a glass case! It was incredible to see the actual objects that created history – space capsules from Mercury, Gemini and Apollo, the first plane to break the sound barrier, the space shuttle – and for these objects, in my opinion, strict preservation is the most appropriate action.

For others, it was difficult to appreciate an object's true significance without seeing/hearing/feeling it doing the job it was designed to do. I would have liked to see just one of the many Wright Flyer replicas demonstrating why it was so significant – ie. by actually flying!

When I asked at the smaller organisations about archives the usual response was "they're in a basement/room/boxes/etc. but we don't really know what's there".

Operating heritage

Fortunately, as in Australia, the enthusiast sector has assumed responsibility for preserving operating examples of much engineering and industrial heritage, from buildings, to aeroplanes, to railways, to……

Image above: Cass Scenic Railway (Cass, West Virginia). Cass has the largest collection of operating Shay geared steam locomotives.

Image left: The EEA AirVenture Oshkosh, Wisconsin Air Show – hundreds of flying heritage aircraft all requiring specialised engineering support. The plane everyone is examining is a (still flying) B-17 Flying Fortress bomber, of a type used in WW2..

There is a real and growing demand for engineers to contribute their professional skills to all forms of heritage preservation.

Resources

Of course, there is never enough money.

As in Australia, technology heritage organisations compete with other "cultural" organisations for shrinking government funding. Technology centres are not considered to be "cultural" in the same way an art gallery or theatre or architecture is considered "cultural" and although there is a much higher level of personal philanthropy in the US, it seems that it is more socially acceptable to donate money for art, sculpture or theatre than technology.

Many technology museums market themselves with "cultural events" such as music concerts, art exhibitions, etc.

Image above: A pair of double helical pinion gears at the National Museum of Industrial Heritage, artistically posed. The principle was pioneered by André Citroën. These were once meshed & drove a rolling mill. Look for the badge on the next Citroen car you see!

Our US visit coincided with the US school summer holidays and everywhere we went we were mobbed by children on summer camp excursions. Technology museums seem to be prime destinations for children's outings (noticeably not the art galleries or theatres we visited). The museums cater for this with programmes suited to school children – incorporating science themed practical exhibits.

I asked myself "why do we rely on technology museums to teach children fundamental scientific and mathematical concepts?" and "why don't we promote these organisations as custodians of knowledge for all of society?". Surely, adults can be educated and entertained too!

I also ask, "why is it considered cultured to visit an art gallery to experience a Monet or Rodin but not a museum to experience a Brunel or an Edison?"

Engineering and Industrial Heritage in USA

50th Anniversary of the start of the Apollo program

I had the opportunity to hear former Apollo astronauts and Apollo 13 Flight Director speak casually about the space programme. To hear from the people involved speak of what engineers achieved in such a short time was a great privilege. I hadn't fully appreciated just how real the "space race" was, how every mission was at the cutting edge of technology and included something never done before. It also brought home to me (and was stated by the speakers) that ordinary people (most were engineers and/or pilots) can achieve extraordinary things.

I was especially interested to hear first-hand what happened during the aborted Apollo 13 mission from Jim Lovell (Commander), Fred Haise (Lunar Module Pilot) and Gene Kranz (Flight Director).

Firstly, it wasn't as dramatic as portrayed in the movie. Gene Kranz did say "failure is not an option" but the team just put their heads down and solved the problems one by one – more about training and discipline and determination than inspiration.

I also hadn't appreciated how much was still done manually

The pilot actually flew the spacecraft himself. Jim Haise explained how he flew the lunar module (their "lifeboat") but had to learn quickly how to fly it with the control module attached – centre of mass and manoeuvrability completely changed.

Computers were still in their infancy (1970) and were employed mainly for trajectory calculations. When the computers were shut down to conserve power and restarted there was a "correction" required (they'd just travelled several hundred thousand miles) which had to be calculated with pencil and paper by Jim Lovell. He got it right.

Gene Krantz was asked about the age of the team who devised and implemented the solution at Mission Control. The median age was 27-28 years!

How do we preserve intangible knowledge like this? – what really happened!

Bethlehem

Image right: The Bethlehem Steel emblem – the wide-flanged beam.

Bethlehem, in the Lehigh Valley Pennsylvania, was the home of Bethlehem Steel – one of the largest iron and steel producers in the world until the 1950s and completely shut down by 2000.

Bethlehem steel is perhaps best known for its adoption, in 1908, of the Grey Mill (designed by Henry Grey). This was a revolutionary rolling mill with horizontal and vertical rolls which produced large, wide-flanged structural steel which allowed architects and builders to build above the existing 20-storey height limit and led to the era of the skyscraper. It is claimed that this mill produced steel for 85% of the New York skyline up to the 1970s as well as major structures such as the Golden Gate Bridge.

The mill continued in operation until the steel plant closed in 1995. The mill itself was scrapped though the archives are thought to survive. No-one is completely sure since the documents rescued from the tip have not been reviewed.

When the plant closed a comprehensive heritage assessment and plan was prepared and partially implemented. Most of the significant structures escaped destruction but none of the machinery was saved (apart from some scavenged by enthusiasts). Some of the structures – for example, a row of five intact iron blast furnaces dating back to the early 20th century are unique and of very high heritage significance.

Images, left & right: The world's largest collection of intact blast furnaces and blowing engines at Bethlehem Steel.

What does one do with a disused iron and steel plant?
Most of the structures sit derelict today with no preservation activity at all.

Engineering and Industrial Heritage in USA

City heritage plans focus on the pre-1900 and more "picturesque" heritage of Bethlehem. Management of this part of Bethlehem's heritage is of a very high standard and makes Bethlehem an attractive place to live and visit – but what about 20th century industrial heritage?

Sands Casino group bought the former Bethlehem Steel site and has built a casino which contributes significantly to the economy. All casino buildings and the "cultural centre" are new with some token acknowledgement of the site's industrial past such as using the ore-bridge to mount the casino sign, some rough cast concrete, exposed steel beams and framed blueprints on the interior walls of the hotel.

Image left : on one side of the street, the new Sands Casino Hotel.

Image right: on the other side of the street, the former Machine Shop.

A large panel on the wall of the new "cultural centre" (bar, café, gift shop, exhibition space, theatres) itemises the donors to its construction. I was surprised by the number of donors, including many individuals, who contributed over $1 million. One hundred metres away in one direction the largest and most complete set of blast furnace blowing engines in the world sits deteriorating while 20 metres in the other direction former mill buildings suffer the same fate.

Image left : on one side of the street, the new Cultural Center.

Image right: on the other side of the street, former industrial buildings.

I couldn't help asking "why build a brand-new building when there is a perfectly sound (and, to my mind, suitable) heritage building right next to it?" I suspect that there are dozens of reasons why the old building isn't suitable – even I could see the "challenges" – new structural loadings, accessibility, asbestos removal, fire safety, etc.

Then I decided that these are just problems for engineers to solve. — It is possible!

There is even one example on the site – National Museum of Industrial Heritage – the only re-used building (see photo on the first page of this story).

In 1908, it wasn't possible to build a building higher than 20 storeys, then Henry Grey designed his rolling mill and from then on it was possible.

Technology is only ever part of the solution. We need to teach engineers how to solve these problems and to address professional and community attitudes – it is possible and worthwhile and rewarding to re-use heritage structures and objects.

Engineering Heritage Australia is making a valuable contribution to preserving all forms of knowledge of engineering and industrial heritage through its heritage education programme for engineers, through its continuing engagement with the community and decision-makers and through working with other heritage professionals and organisations to demonstrate possibilities available to owners and custodians of heritage structures and objects.

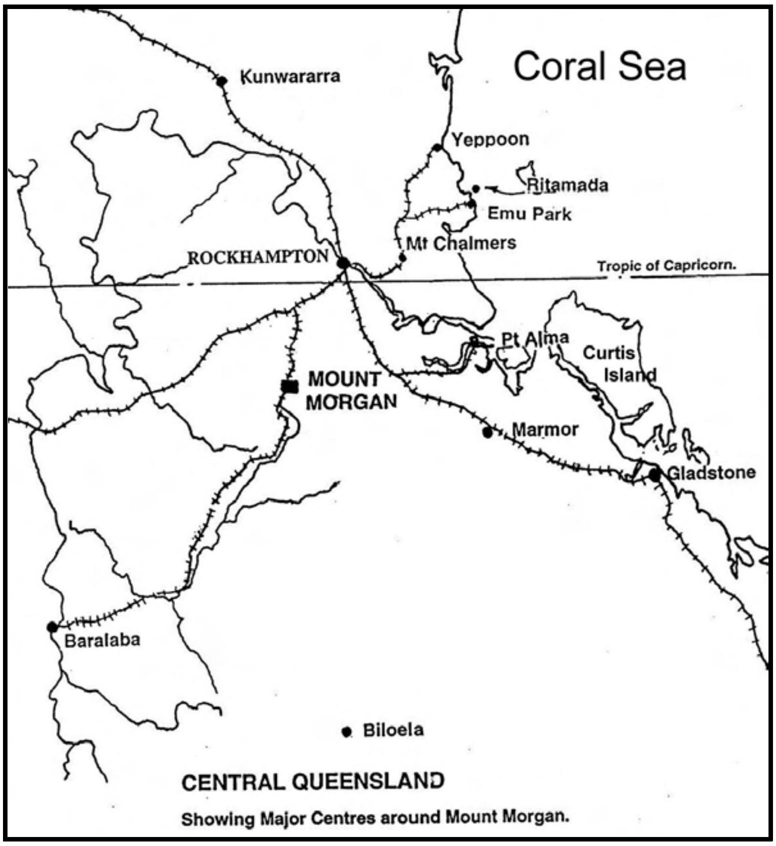
Neil Hogg, Chair, Engineers Australia National Engineering Heritage Committee.

All photographs were taken by the author.

Moving the Golden Ore of Mount Morgan

From horse drawn drays to high-tech machinery – 1882 to 1927.

Mount Morgan is a gold and copper mining town in Central Queensland that, throughout much of its life, has experienced only the effect of one major mine and one mining corporation involved in its activities at any one time. The existence of a single mine and the longevity of the mine, from 1882 to 1990, make Mount Morgan outstanding in Australian mining history.[1]



The old German miners had a saying 'Gold wears an iron hat' and nowhere was the saying better confirmed than in the ironstone 'hat' that deceived prospectors into thinking the golden glitter in the rock of Ironstone Mountain, 24 miles (39 km) south-west of Rockhampton in Central Queensland, was 'fool's gold' (iron pyrites).

Image: Map 2 from R F Boyle, "A study of the management & growth patterns of Mount Morgan Ltd, 1929-1950", MA thesis, CQU, 1994.[2]

Only William McKinley, a stockman fossicker/prospector, recognised the wealth that was hidden in that rock. He took only sufficient gold to supplement his meagre wages, happy enough not to further exploit his discovery. However, he was deceived by members of his own family who led Rockhampton hotelier and miner Edwin [Ned] Morgan to the mountain top in July 1882. Taking samples of the rock, Morgan was astounded to discover that each sample he took apparently contained *more gold than stone – if gold indeed it was*.[3] For the rest of his life Morgan was to claim, wrongly, that he was the discoverer of the gold on the place he renamed Morgan's Mount – even though the real discoverer was William McKinley.[4]

Unwilling, or unable, to fund the machinery necessary to develop the place himself, Ned Morgan's older brother, Fred, wrote to Thomas Skarratt Hall, Rockhampton manager of the Queensland National Bank, offering him a half share in the property for £1,200. The original letter, dated August 5th 1882, is archived in the Capricornia Collection [CAPCOL], Central Queensland University, Rockhampton. Thomas Hall quickly brought in Rockhampton lawyer William Knox D'Arcy and grazier William Pattison to invest, not £1,200 but £2,000 in the Mount Morgan Gold Mining Syndicate. This amount represents all the capital ever raised to fund the Syndicate and later the Mount Morgan Gold Mining Company Limited [the Old Company] which followed it in 1886 – everything afterwards was funded from income. Soon after this investment was made, Thomas Hall brought into the Syndicate his older brother Walter Russell Hall, already wealthy through his partnership in Cobb and Co coaches and from his extensive pastoral activities.

The lucky Syndicate members & employees at the top of Morgan's Mount looking very pleased with themselves in the first days of operation in 1883.

Image: CAPCOL Collection.

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1 The Heritage Register entry for *St Mary's Church, Mount Morgan* at https://environment.ehp.qld.gov.au/heritage-register/detail/?id=601690 has interesting information about the mine, the town, and a benefactor of the church, Wesley Hall, who was Mine Manager from 1882-1891.

2 Central Queensland University.

3 B.G. Patterson, The story of the discovery of Mount Morgan, lecture delivered on 27 May 1947 to the [Royal] Historical Society of Queensland, p.16.

4 ibid, pp.19-20.

Moving the Golden Ore of Mount Morgan

With the exception of Pattison, whose fortune was lost through the alleged deceit of the others, and the Morgans, who sold out, the other Syndicate members went on to own over seventy percent of the shares in the Old Company when it was floated in 1886 and by the turn of the century had enjoyed a return many hundreds of times their original investment. Their fortunes ultimately funded the discovery, by D'Arcy's interests, of oil in the Persian Gulf, Tom Hall's family interest in research facilities at Oxford University and Walter's legacy to the formation of the Walter and Eliza Hall Trust in Australia.

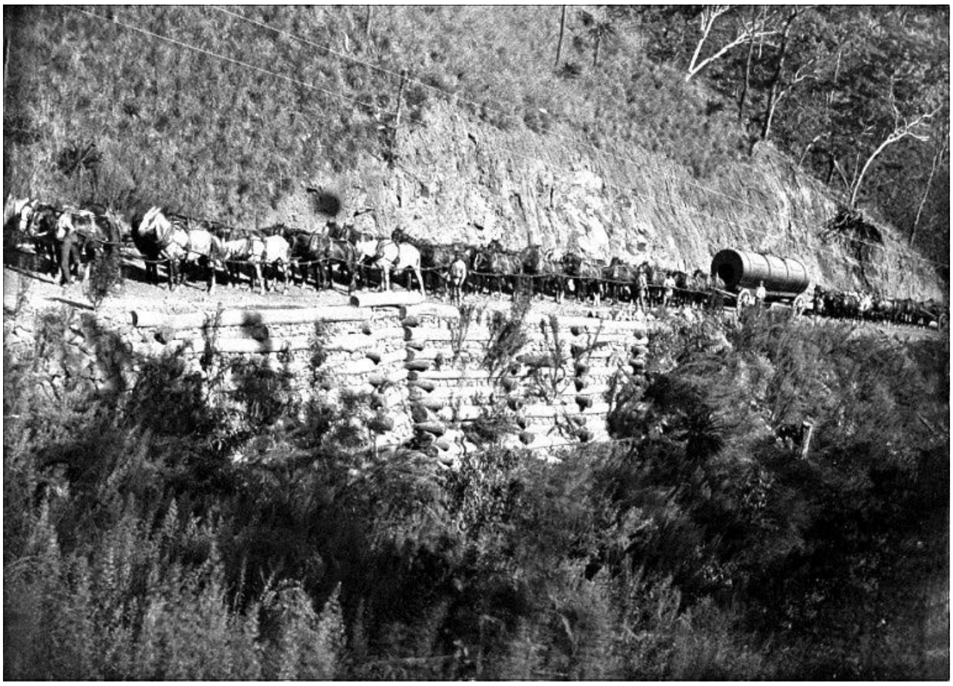
For more than one hundred and thirty years, many thousands of words have been written about the geological, mining, metallurgical, engineering and social history of Mount Morgan and those words present many fine examples of engineering heritage significance because, as the late Emeritus Professor Ray Whitmore pointed out, *There can hardly have been a hard-rock mining procedure or metalliferous extraction process that was not tried out in Mount Morgan at one time or another.*[5]

It would be easy to write a largely technical story about each area of the place including the development of mining programmes but this story will concentrate on the way materials handling changed during the forty-five year life of the Old Company. In 1910, Norman White, the Chief Engineer of the Mount Morgan mine from 1907 to 1913, wrote:

> *Nearly all problems in mining engineering involve the transport and distribution of materials from place to place, and in general the most economically managed mines and plants are those in which the transport of materials has been carried out most efficiently. Of all these transport problems, the hoisting of ore out of the mine and the distribution of same to the various treatment works is perhaps the most important.*[6]

So here we should look at transport of material at Mount Morgan, progressing from horse drawn drays, through an aerial tramway to early steam excavators to ore trucks and locos on rails and finally to a semi-automatic inclined shaft winding engine.

The centre of "top quarry", the primitive operation at the crown of Ironstone Mountain in ca1884. Image: Hempseed Collection.



A team of 52 horses hauling a boiler for the Upper Works up the 1 in 5 slope of Razorback Road, ca1887. Image: Hempseed Collection.

No doubt the Syndicate was anxious to start realising on its investment but crossing the steep Razorback Range from the Fitzroy River plateau to the Dee River valley, which Morgan's Mount overlooked, presented a barrier to the transport of the largely Rockhampton manufactured heavy engineering equipment required to establish the first stamp battery on the banks of the Dee River.

The Razorback Range is about three quarters of the way from Rockhampton to Mount Morgan and at an elevation of around 300 metres. Despite the story of an old sailor's successful intervention in the method of hauling these machinery parts over the steep slopes using ropes *as thick as a man's arm* and labouring over crab winches, it was seven months from the formation of the Syndicate on the 1st September 1882 before all the plant was in place.[7]

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5 Cited in R. F. Boyle, *The legacies of Mount Morgan*, AusIMM Bulletin, July-August, 2002.

6 N. F. White, *Head-gear and electric winding plant at the Main Shaft*, paper No 199, Transactions Aus. I. M. E, Vol XV, II, Introduction.[White]

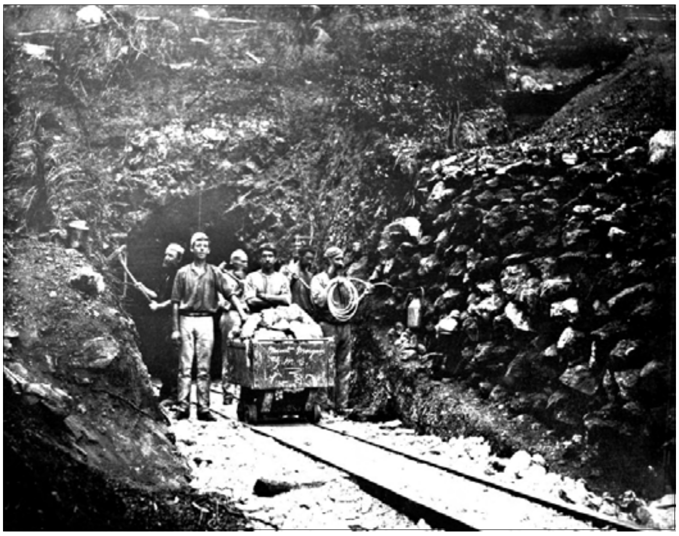
7 B.G. Patterson, *A history of The Mount Morgan gold mine 1908-1927.* Typescript unpublished [Patterson], pp. 37-38.

An Abt locomotive pushing a rake of goods wagons up the Razorback incline – in the early 20th century. The concrete wall (lower right) is the only remnant of the line still existing. Image: CAPCOL Collection.

The steep Razorback inclines would continue to hinder the movement of people and goods for another sixteen years before an Abt Rack Railway system, to fund which the Old Company had been reluctant to spend a month's dividend, would provide easy and economical access for the next fifty-five years. Even when built it was the Queensland Colony which paid for the line. Although the rack section was only one mile and thirty-five chains (2315 metres) long it rose 374 feet (114 metres) with an average grade of 1 in 20.3 and a short section of 1 in 16½. While an Abt railway, longer but with similar gradients, still remains at Mt Lyell, Tasmania, all traces of the Razorback Range rack railway were removed in 1953 when it was replaced by a more suitably graded deviation built to serve heavy coal trains hauling from the Moura coal mine, south of Mount Morgan, to the port of Gladstone.[8]

The outcrop sampled by Morgan at the mountain top (340 metres elevation) was dug out with picks and shovels from little quarries but gradually, as mining progressed, ore was won from underground tunnels and heavily timbered chambers (stopes) still no more than a few hundred feet below the summit.

Loading ore into drays in the top quarry. Wesley Hall, the Mine Manager from 1882 to 1891, said "Six men can comfortably break sufficient stone to keep the battery supplied". Image: Hempseed Collection.



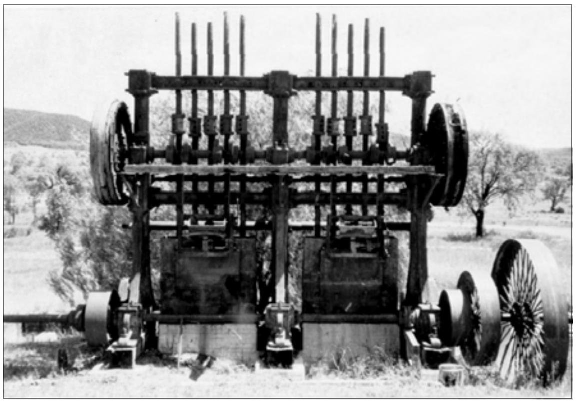
When mining was extended to include underground tunnels, ore was pushed out by hand in little rail trucks but still dumped into drays for transport down the hill. Image: CAPCOL Collection.

The first battery was erected in a U bend of the Dee River, some five hundred and fifty feet (168 metres) below the mountain top, with rough hillside tracks providing the only access down the steep mountain slopes. Because of these slopes, getting the ore down the mountain was difficult so it was carted in tip drays to the top of a crude timber 'shoot' feeding other drays which then wound their way slowly down tracks to the battery.

The 'shoot' [Morgan's spelling] passing ore from the top quarry to drays for transport down the mountain to the riverside stamp battery. The building of this shoot was one of the conditions specified in Morgan's letter to Hall. Image: CAPCOL Collection.

8 J.W. Knowles, *The Mount Morgan rack railway*, self published, 1982.

Finally in February 1883, with machinery in place, the little ten-head stamp battery went into service with Ned Morgan in charge of the whole operation. Contemporary photographs show stacks of firewood which fuelled the boiler.



The remains of the first ten-head stampers installed in the Battery in 1882. Image: unidentified source, CAPCOL Collection.

The first stamp battery ca 1883. Note the stacks of firewood, fuel for the battery boiler. Image: Hempseed Collection.

Several hundred men cut and carted timber from the surrounding hills to provide fuel for the boilers and the furnaces of all the treatment plants which followed. By 1892 the entire Works were consuming 80 tons of firewood a day.[9] Timber consumption for fuel was gradually reduced as older plants shut down and, after the construction of the Abt rack railway brought coal to the new Electric Light, Power, Pumping and Air Compressing Works (the "Electric Light Works", completed in 1898), all the new plants built were electrically driven and furnaces were coal fired.

The battery was intended to recover the gold in the classic mercury process. The stampers in the battery crushed the ore which passed over copper plates coated with mercury where the gold formed a gold amalgam which was later processed to produce gold bullion. Any gold which did not bond with the mercury passed to waste. But here the recoveries were challenged! Because the gold was so fine (invisible to the eye and hard to see even under great magnification) the stampers were unable to grind the stone finely enough to separate or uncover the gold. Over sixty percent of the gold refused to amalgamate and washed over the plates – the losses were extraordinary.

There are no records of the gold content in the ore – rumours suggest at times there were several hundreds of ounces of gold per ton – but in fact it was unusual for gold input to fall below 8 ounces per ton. Nevertheless the gold going to waste down the river, containing as much as four or five ounces of gold per ton, was many times what other miners would have been delighted to mine and treat.[10] The mercury-rich tailings going down the river presented the first recorded event of pollution of the Dee River, events that continue to the present day.

But despite the losses the returns were extraordinarily high. The recovered gold bullion contained an amazing 99.7 percent pure gold, so the plant kept operating and the lost material was eventually stockpiled for later re-treatment instead of being washed down the Dee River. The Syndicate maintained tight secrecy but the majority of the people of nearby Rockhampton must have wondered why the gold passing through the port had mysteriously increased from 3,209 ounces in 1882 to almost 25,000 ounces in 1884. No one suspected the source until a local newspaper reporter started asking questions and the secret was out. It was suggested Tom Hall had been able to use his position as bank manager to disguise the movement. The Solicitor of the Old Company, Rees Jones, says that in the first four years a throughput of only 10,000 tons of ore yielded 90,000 ounces of gold worth some £400,000.[11]

Ned Morgan was said to have been a better boxer than he was an engineer and when the Old Company was floated in 1886 he was replaced as General Manager by James Wesley Hall, the younger brother of Walter and Tom. Working quietly in the background, Wesley Hall and his Chlorinator George Arthur Richard led the task of modifying the work of 'experts' brought in to resolve the challenges of poor recoveries. Hall & Richard introduced successful chlorination processes which overcame most of the early problems and, as the gold content of the ore decreased, enjoyed significant cost advantages.

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9 F.W. Sykes, *The Mount Morgan gold mine, Queensland,* John Sands Printer, Sydney, 1893, p.72.

10 Patterson, pp.39-40.

11 Rees Jones, *Gold mining in Central Queensland and the Mount Morgan mine*, 1913, the Morning Bulletin, Rockhampton, p.18. Also see Rees Jones in: http://adb.anu.edu.au/biography/jones-rees-rutland-6880

The 'experts' had included Messrs Newbury and Vautin whose iron barrel chlorination technology had largely solved the problem of poor recoveries of gold, but with poor throughput of ore and at high cost. In the previously used mercury process there was no attempt to treat the ore except for crushing it before adding mercury. Subsequent processes roasted the ore before, in some manner, adding chlorine either gaseous or as diluted liquid. Fairly early on, the most successful had been the aforementiond Newbery-Vautin process.[12]

The so-called Lower Works, built in 1886 near the river and alongside the battery was treating 500 tons a week. It used the Hall & Richard techniques with outstanding operating and financial results. Even at this throughput the crude shoot and dray transport still provided sufficient ore to keep the Lower Works operating.

But when the much larger and more efficient Upper Works, built closer to the mine workings and commissioned in 1888, and using the already proven Mount Morgan Barrel Process was commissioned (a modification of the Newbery-Vautin process with a throughput of 1,000 tons a week), more efficient haulage from the quarry to the plant was required.

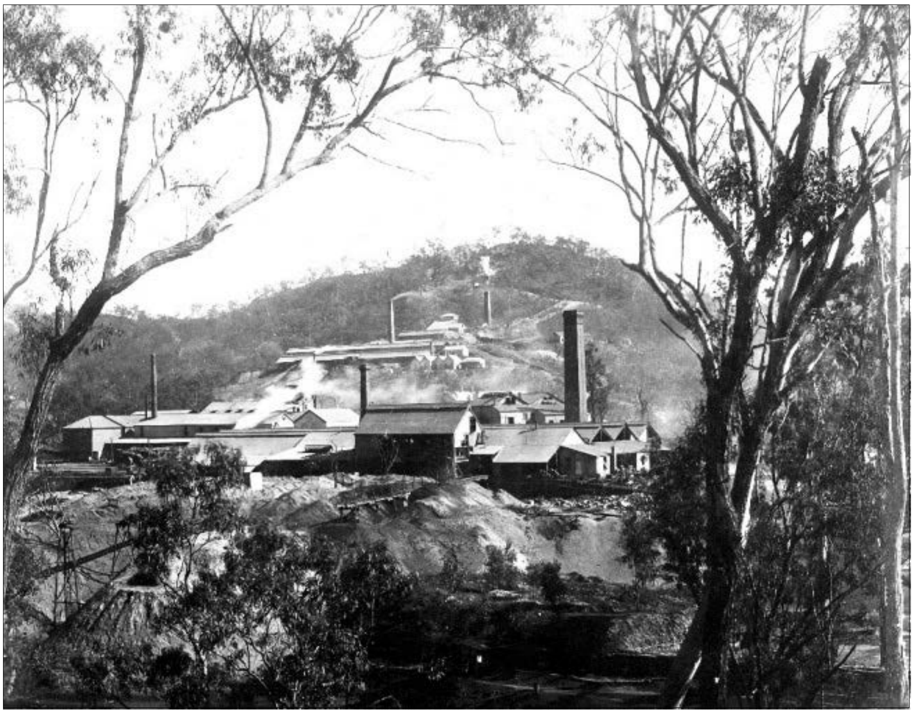

Image right: Shows the Lower Works in the foreground, then the new Upper Works and the summit of Mount Morgan. See the tracks down the mountain just above the peak of the brick stack. From CAPCOL Collection.

Consequently, in January 1888, a highly successful aerial tramway, or cableway, over 3,300 ft. long, operating from the mountain top, using steel buckets each carrying about two hundredweight of ore, replaced the drays to transfer the ore to both the Upper & Lower Works. American engineer Charles Kolling, with previous experience of aerial tramways in the United States, was responsible for its construction and for its early operation.

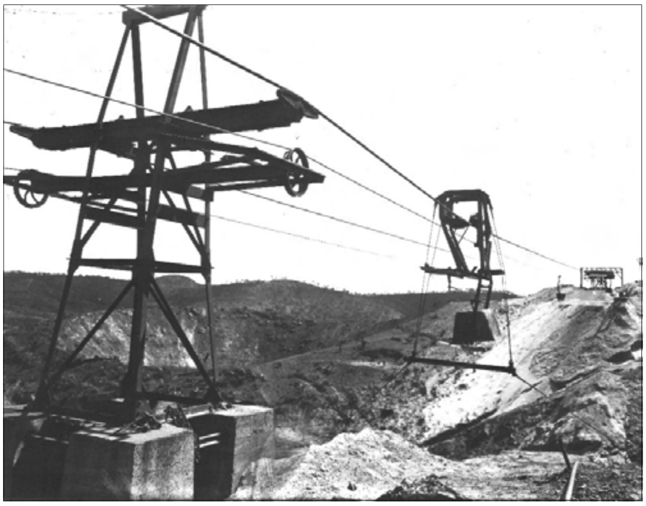

Image above:
The aerial tramway or cableway at the mountain top showing the headworks. CAPCOL Collection.

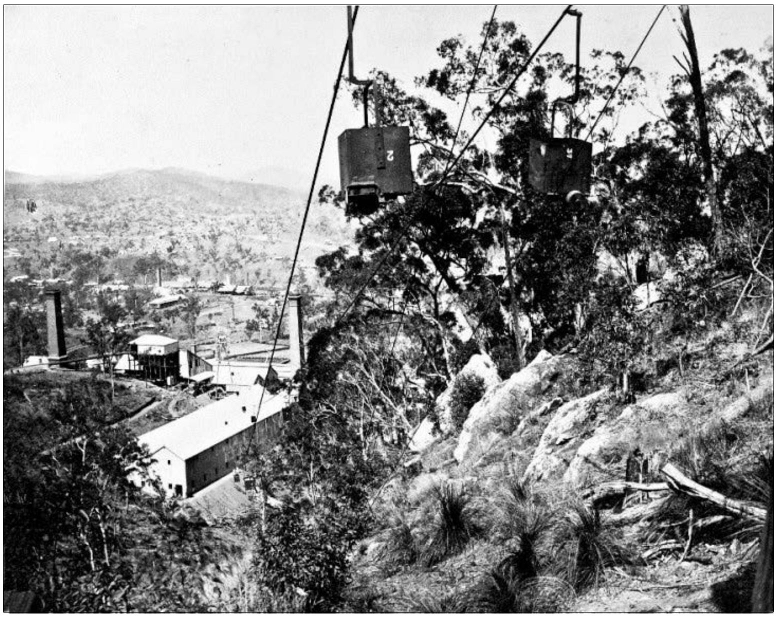

Image right:
The aerial cableway from the quarry to the Upper Works. The Acid Works producing sulphuric acid for chlorine manufacture is in the foreground and the township may be seen across the hills. The photograph is of unknown origin but is reproduced as a sketch in Sykes, facing p.66.

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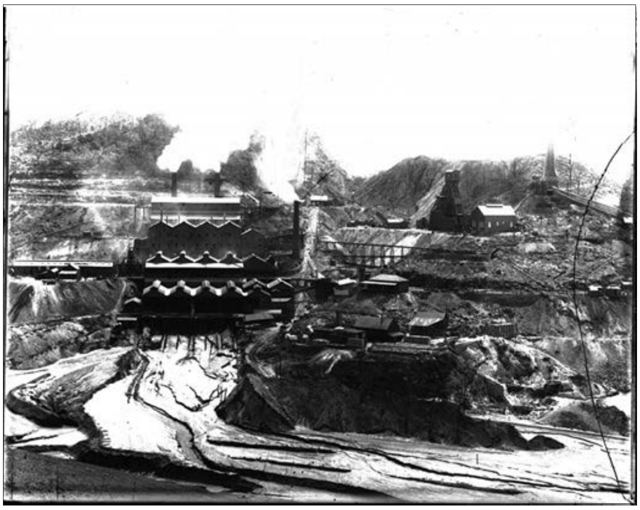
12 Described in Scientific American Supplement No. 620, New York, November 19, 1887 - *the Newbery-Vautin Chlorination Process.* See http://chestofbooks.com/crafts/scientific-american/sup5/The-Newbery-Vautin-Chlorination-Process.html

Moving the Golden Ore of Mount Morgan

Wesley Hall retired in 1891 content in the knowledge that, under his management, shareholders had received regular monthly dividends which in, July 1889, peaked at £125,000 and dividends for the twelve months of 1889 totalled £1,100.000. Mount Morgan dividends that year outperformed Ballarat and Bendigo.[13] And Tom Hall, Walter Hall and Knox D'Arcy would have received some seventy percent of these dividends.



The high grade of ore in the gold-rich oxidised ore[14] that topped the mountain, plus the efficiency of the treatment plants had produced these high dividends but, while gold values were still comparatively high, there was a gradual fall in the head grade of ore as the oxidised ore reserves diminished. To compensate for the changes in the ore grade, treatment plants became increasingly larger culminating in the construction, between 1896 and 1897, of the West Works designed to treat 10,000 tons of ore a month.

The plant acknowledged lessons learned in the Upper Works and included the Hall-Richard process, a development of the work of these two engineers and an improvement on the Mount Morgan Barrel Process. On completion, the West Works was reputed to be the largest chlorination works in the world.[15]

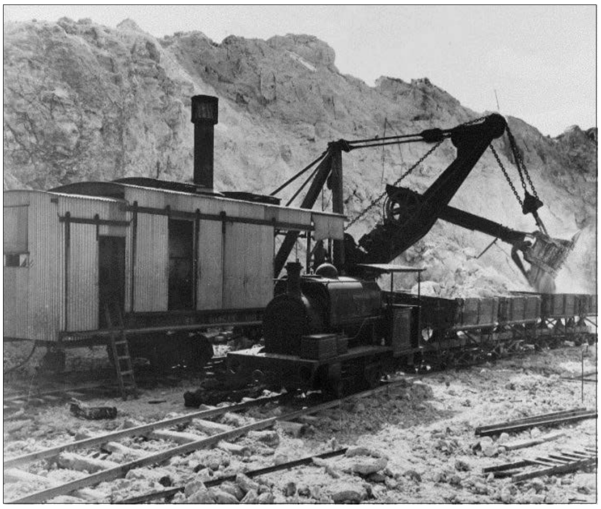


Image above: The West Works post 1905. The new Main Shaft Headgear and Winder House are to the right of the picture. CAPCOL Collection.

Image left: Bucyrus 65 ton rail mounted excavator serial No 506 loading waste into 3ft 6in gauge Aurora side-tipping trucks hauled by a 10 ton Hunslett loco. Seale Collection.

With the new plant built lower than the main tunnel level, ore skips were initially pulled out of the tunnels straight to the Works using an endless rope system but when this 'did not give satisfaction'[16] it was replaced by little steam locomotives which in turn gave way to small electric locomotives after the commissioning of the Electric Light Works in 1898.[17]

However, by this time large quantities of low grade sulphide ore were appearing – ore with very low gold content but containing copper. This ore could not be treated by the techniques in place. Experiments in the West Works led to a decision to build yet another plant, one capable of treating ore containing less than a third of an ounce of gold to the ton 'at a bare profit'- a far cry from the halcyon days of 1883. The result was the Mundic[18] Works, the first stage of which was commissioned in the last days of the nineteenth century.

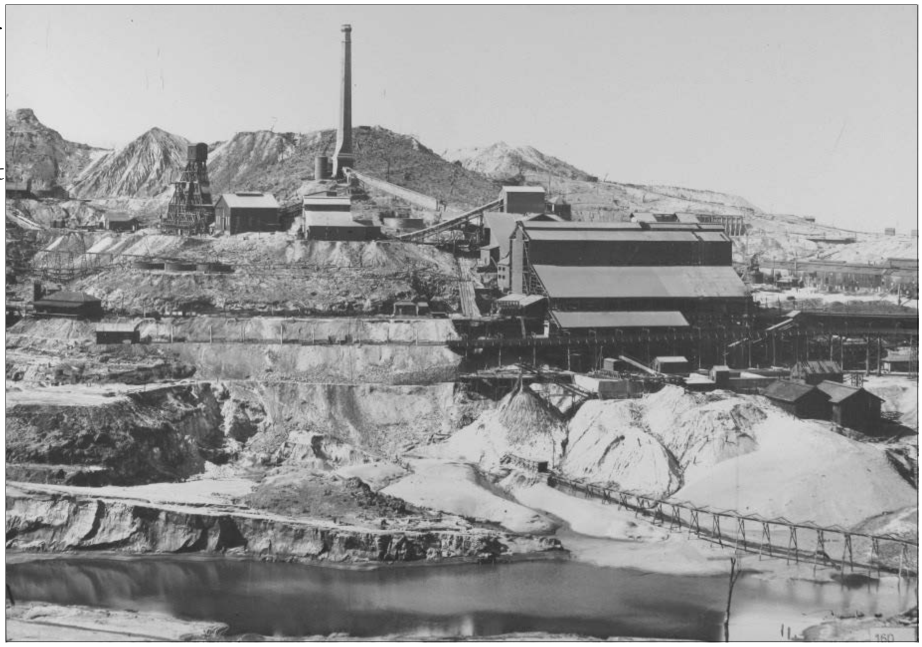


Image right: The Mundic Works circa 1910. The earlier West Works are out of view to the left. The 1903-5 head gear and its winder house are left of the big stack. CAPCOL Collection

13 Sykes, p.84.

14 See https://australianmuseum.net.au/geological-ore-deposits

15 See K McQueen, *Early developments in treating pyritic and refractory gold ores in Australia*, JAMH, V.10 Oct 2012, pp88-102.

16 Patterson, p.70

17 C H Humphreys, *West Works – Mount Morgan (Queensland) chlorination*, paper No 200. Transactions Aus I M E, Vol XV, p. 366.

18 Mundic - a Cornish word for iron pyrites. Mundic, or pyritic ore, formed the main orebody mined at Mount Morgan until 1981.

In 1901 it was decided to mechanically mine the old quarry and the stopes that lay below it down to the 450 ft level, salvaging what oxidised ore remained, mining the sulphide ore that had appeared and discarding waste to dumps. A 35 ton Bucyrus rail mounted excavator[19] with associated steam locomotives and side-tipping rail wagons operated from 1903 until 1908, removing 1,000 tons a day directly from the quarry faces and replacing 20 years of hand shovelling. A smaller Whitaker excavator operated to mine material from more inaccessible areas.

Image above: The Bucyrus excavator removing the remnants of the oxidised gold ore, old stopes, sulphide ore and waste, circa 1905. Seale Collection.

Image left: Whitaker rail-mounted excavator ca 1906. Seale Collection.

Image below: Whitaker excavator and Hunslett locomotive working in a difficult position mining out the old stopes, circa 1908. The Copper Works stack is in the background. Seale Collection.

The oxidised ore went directly to the West Works and any sulphide ore to the new Mundic Works. Coinciding with the exhaustion of the oxidised ore, the West Works closed in 1910. The Mundic Works were built essentially to treat the low grade pyritic gold/copper ore and, after 1905, to produce feed for the new Copper Reduction Works, with its output of blister copper.

While the Bucyrus and the Whitaker were suited to the open ground, they were too big to use in the network of tunnels. At some time after 1898, but possibly not until around 1913, the electric loco haulage out of the tunnels was, in turn, found to be unsatisfactory. A study indicated that it was more economic to use draught horses to pull the wagons. Horses were stabled in a facility on the eastern side of Dairy Creek which fed into the Dee River [the Horse Paddock]. In the morning the horses were driven down the Linda Shaft, one after the other, peeling off at the appropriate level. The Linda Shaft provided 'supply' access to the underground tunnels and workings. It was built in 1908 with a decline of 1/3 which was an easy slope for the horses to negotiate. The shaft started at Linda Level, 454 ft below the original Mountain top and the horses could exit at each of the working levels – 574, 650 & 750 ft below the top. Their work was pulling loaded ore trucks along rails in the level tunnels where the little locos had gone before. They would be hitched to 4 trucks and it is said if anyone tried to hitch up a 5th they would stand and refuse to move. At knock-off time they would run up the inclined shaft and head for the showers and feed in the Horse Paddock. Obviously they did not want to go to work and when released were glad to race up to get to their bath and food. The horses were spelled on Sundays at a paddock to the south of the town – but on Sunday nights some of them would hide behind trees to avoid being taken back to work. The underground mine was destroyed by fire in September 1925 so there was then no need for the horses which were auctioned off.[20]

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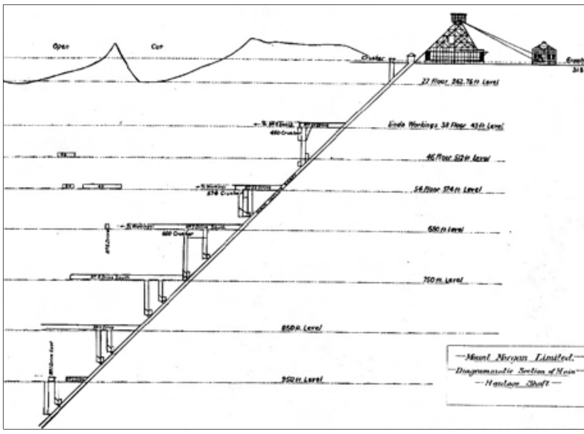
19 The history of the Bucyrus excavator may be found on the Victorian Heritage Council site: http://vhd.heritagecouncil.vic.gov.au/places/11125. The machine has been rebuilt and is a working exhibit at the Lake Goldsmith Steam Preservation Association. For videos of it in operation see: https://www.youtube.com/watch?v=Ur_0YitNIu8 and https://www.youtube.com/watch?v=fHsXbKRV1Tg.

20 Personal communications to the author from Frank Cunningham, whose father was in charge of the horses at Mount Morgan.

Moving the Golden Ore of Mount Morgan

Between 1903 and 1905, in order to access the massive pyritic gold/copper orebody which had been proven deep below the surface, a new inclined haulage shaft, the Main Shaft, was sunk on the southern wall of this orebody. Excavated at an angle of 45°, the shaft was sunk from the approximately 320 ft. level below the original mountain top, through the ore body to the 1035 ft. level. These works were under the supervision of Assistant General Manager, Percy Seale while the electric winding engine was the responsibility of Chief Engineer, Norman White. At the time, the shaft was the largest example of its type in Australia.[21] A pneumatically operated tramway type drum controller (pictured below with the winder) automatically controlled the acceleration and speed of the winder on receiving a single directional electrical signal initiated by the driver. It was Mount Morgan that pioneered this electric winding gear control technology. Manufactured by the Marlborough, Queensland, firm of Walkers Limited, the winding gear installation was the first of its kind in the country.[22]



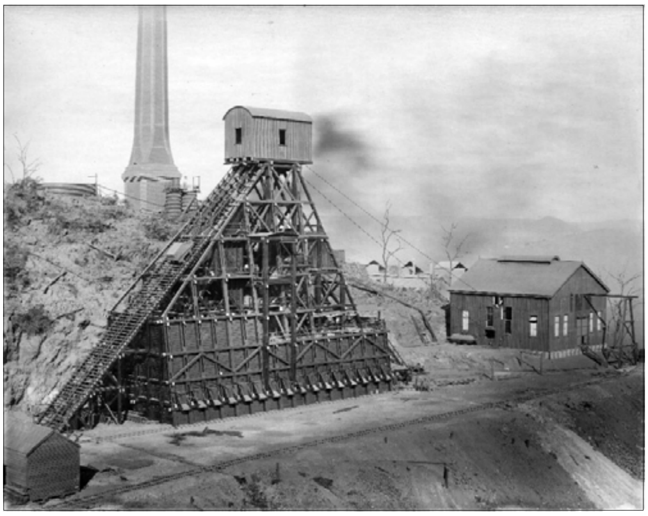
Cross section of the Main Shaft, a sketch drawn post 1933. Image from CAPCOL.

Built entirely of timber, the headgear structure contained storage bins, two gyratory crushers and a sorting conveyor on which the copper ore was separated and dropped into five-ton bottom dump railway hoppers in a tunnel below. Steam locomotives hauled the trucks directly to the recently commissioned blast furnaces of the Copper Reduction Works. The pyritic gold ore remaining was drawn from the storage bins through chutes at the sides into side-dump trucks, which were hauled by electric locomotives to the Mundic Works.

Image left: Percy Seale, the Chief Accountant, shift bosses and workers at the surface entrance of the Main Shaft during the commissioning, 1905. Seale Collection.

Image below: The Main Shaft Headgear and the Winder House, 1905. In the rear left is the Mundic Works Stack and to the left of the Winder House the top of the Mundic Works. Seale Collection.

However, as the copper content of the ore increased, the original Mundic Works were unable to treat it satisfactorily so yet again, in 1912, new technologies were introduced, this time within the Mundic Works building under the name *The Concentration Mill*.[23] Progressive changes saw the above ground plant on this site continue under Mount Morgan Limited (the New Company) as No.1 Mill, until it closed in 1982 but, until the Main Shaft was mined out in 1970, this winder supplied its feed.



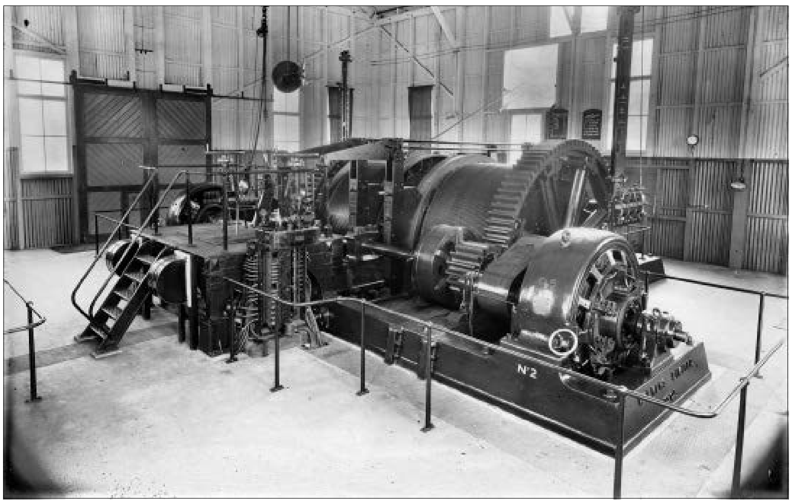
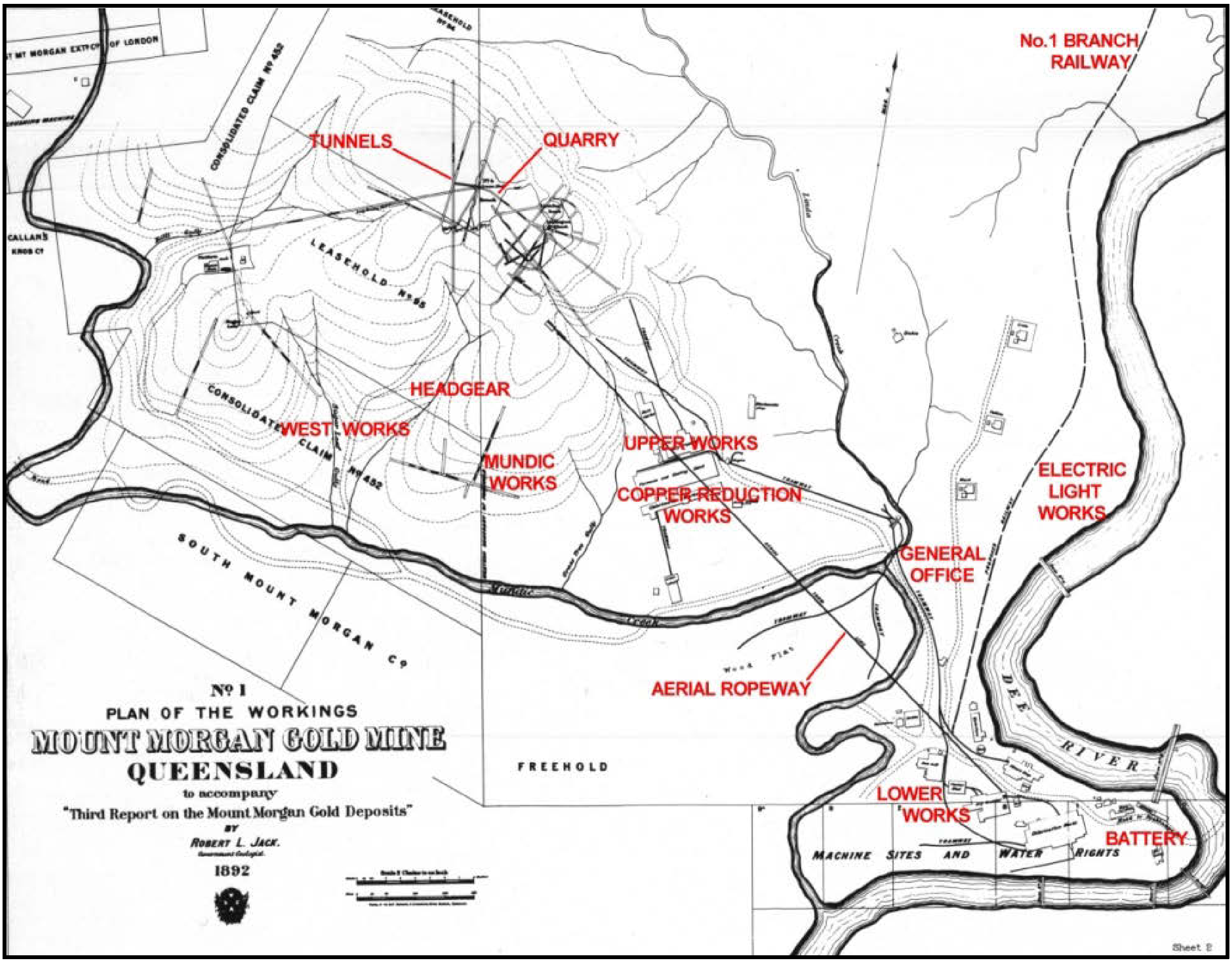


Image left: The Main Shaft double drum winder, 1905. Seale Collection.

21 Boyle, Wilson and White, *Mount Morgan Queensland, Marvellous Mountain*, AusIMM Centenary Conference, 1993, p.332.

22 For a full description of the plant, see Boyle, Wilson and White, p.335.

23 *The story of the Mount Morgan Mine, 1882 -1957*, Mount Morgan Limited, 1957. unnumbered page.



Map of Mount Morgan Gold Mine made in 1892 for the Geological Survey of Queensland by Robert L Jack. The approximate location of objects or places referred to in this story are annotated in red. Some objects, such as the West Works, the Mundic Works, the Headgear, or the Electric Light Works, did not exist when the map was made. Image source: "Gold Diggers & Diggings", ed. Derrick I Stone, pub.1974.

Although horses had replaced electric traction underground, the introduction of the Main Shaft Winder and its associated equipment was the last major change in the method of transporting ore above ground, and the Shaft operated until September 1925 when 'a thousand angry men' marched on the Mine, ejecting officials and shutting off all electric power. With no underground ventilation, and probably because of spontaneous combustion of the pyritic ore, an uncontrollable fire broke out destroying the heavily timbered underground workings and most of the Main Shaft.[24]

Major mining ceased and two years later, although test work had confirmed Open Cut mining was a feasible option, the Old Company placed itself into voluntary liquidation at the end of 1927, repaying over one hundred and nineteen percent of its nominal capital to shareholders. During its life, it had produced 5,345,000 ounces of gold and 140,000 tons of copper from its single orebody. It had paid over £11 million in dividends, returning over 500,000 percent on the original investment.

But it left behind over eight million tons of ore, providing a new company, Mount Morgan Limited, with the reserves it needed to begin operating in 1932. Additional tonnages discovered on the western horizons of the old workings increased these reserves and the mine operated profitably again for a further sixty-one years. For thirty-seven years the refurbished Main Shaft and Winder supplied ore to the many times altered and restructured plant that had once been the Mundic Works. But that is another story!

Dr Ray F Boyle, DipMEE, ADME, MA, PhD, FIEAust, CPEng.

[24] R F Boyle, *Mount Morgan Limited-The Triumphs and Disappointments 1932-1990*, CQUniversity PhD thesis, 2014, p. 5.

Reflections on Engineering in Vietnam

Owen and Helen Peake take a look in 2017

Vietnam is a country of contrasts and breathtaking contradictions. Unsustainable opulence is common but grinding poverty is everywhere. Artistic excellence has clearly been expressed for many centuries yet much of the modern art and construction is shoddy. Sublime engineering stands above cities of endless hovels. We were disturbed by these contrasts.

I had never been to Vietnam before. In my youth I sweated about being conscripted to fight in the Vietnam War but, to my great relief, I wasn't. One of my best friends volunteered and did several rotations flying light reconnaissance aircraft over enemy territory. His experience apparently left him stronger and very grounded. Others went, served and returned as broken men. I got 'conscripted' to Darwin by Department of Works and stayed there for 40 years full of wonderful experiences.

Eventually my wife Helen and I decided that Vietnam was a country we should visit and try to understand better. We spent three weeks there in early 2017 travelling from the delta of the mighty Mekong River in the South to Hanoi and Ha Long Bay in the North. We travelled on an organised tour, mostly by bus, so saw a lot of diverse country. This article isn't a travelogue of our trip – it is about some engineering observations. It also isn't about engineering heritage which is an exceedingly rare commodity in Vietnam.

The first engineering feature was the mighty bridges over the various strands of the Mekong as we headed into the delta. These bridges carry motorways over the very large waterways and all allow generous headroom for shipping which crowded the waterways. It seems that much of this work has been carried out by Japan and every bridge carried the Japanese hallmark of strong but elegant engineering design.

Images, above and left: Magnificent, soaring bridges over the strands of the Mekong River in the delta region of Vietnam.

The bridges are apparently all different in detail. Most are cable-stayed structures but there are some suspension bridges. Their soaring towers make them visible from great distances in the flat delta country. There is nothing utilitarian about these bridges – they are each a statement of strength and muted elegance as they stride across the great river strands.

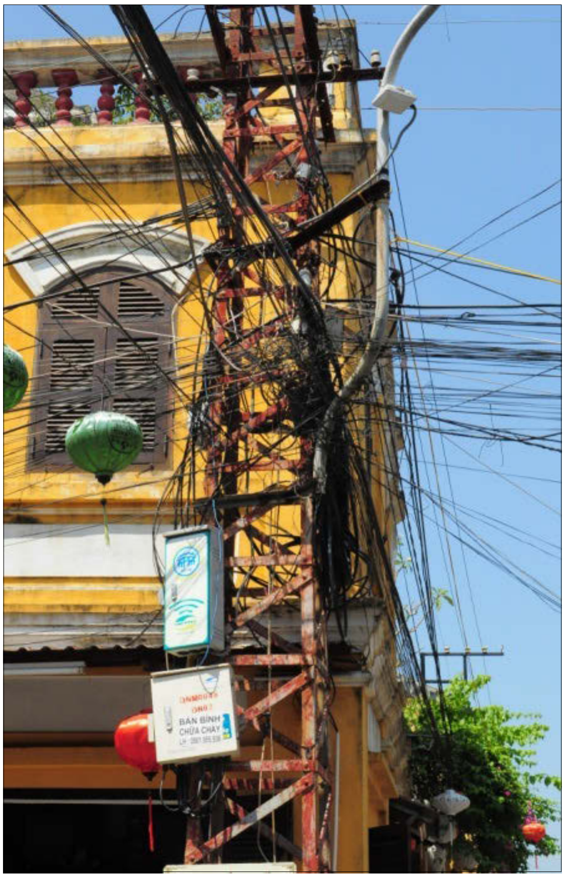
The delta provinces are poor although there is much evidence of great enterprise. The bridges help to lift the heart above the often desperate poverty.

Above: A newer style "pedestal" substation in Hanoi.

The provision of electricity supply in the larger cities of Vietnam is faced with the typical pressures of reducing cost by placing distribution lines overhead versus the greater amenity of undergrounding. Like many Asian cities this leads to chaotic street scapes cluttered with substations, overhead lines, haphazard service arrangements and clusters of revenue meters hanging off poles like the fruit on a pawpaw tree.

There is a propensity to place distribution transformers on pedestals, like statues of long-gone politicians. These appear to be a sensible compromise between the usually-messy pole-mounted substation and the package substation at street level which clearly would take up more valuable space than the pedestal substations which have been adopted.

Above: Traditional pole type distribution substation in Saigon.



With respect to street clutter I have saved the best until last! The telecommunications cables are generally overhead and incredibly chaotic. They are attached to anything which comes to hand such as electricity poles, buildings, trees and probably people if they stood still for long enough.

How the linesmen work out which cable goes where is a deep mystery but it appears that most people get a phone connection and a computer connection somehow.

Images, left & right: Rats-nests of telecommunications cables appear like a form of street art in Vietnam.

Some will recall my previous articles about manhole covers around the world in this magazine. Sad to say there is nothing much left of the French Connection as far as manhole covers are concerned in Vietnam. However I did see a wonderful example of a failed attempt to actually get a manhole cover onto a manhole apparently containing several kilometres of spare electric cable. This was, by the way, in an elegant area of downtown Hanoi.

Image right: The caption for this picture should be: "Sorry boss, I couldn't get the cover on!" Note that the paving of the street around the manhole is well laid slate tiles. By the way the manhole cover is not broken – it is made in three triangular sections.

The heavier end of the electricity system appears quite conventional and well engineered. Transmission lines crisscross the country and substations are often located prominently at the side of highways near the entrances to cities to remind visitors of the beauty of these fine installations. They might have copied this practice from Australia.

Image left: Transmission line tower in rice paddy with three circuits of two different voltages.

Image right: Bulk supply substation alongside the highway.

That is enough about electrics. The Vietnamese love a good ceremonial arch. I live near "Little Vietnam" in Victoria Street, Richmond, Melbourne and there is a ceremonial arch at the Hoddle Street, Victoria Street intersection. In the city of Hue in central Vietnam they have gone one step further. There are many bridges in Hue and one is a fine representation of a dragon. It appears that the structural requirements of the bridge and the form of the dragon have been combined very cleverly – it is a fine looking dragon and the bridge is clearly perfectly functional.

Images: The head and centre of the Dragon Bridge in Hue.

Our Editor would expect me to make some comments about the Vietnamese before ending this article. The Vietnamese are very complicated – they encompass several major variations which constantly interact across their society – the city dwellers vs the country people; the rich vs the poor and the North vs the South.

Several aspects of the Vietnamese stand out for me as defining characteristics.

The Vietnamese are uniformly generous, kind and friendly and it is always a pleasure to be in their country. We, in Australia, having seen a wave of Vietnamese immigration after the end of the Vietnam War have long since come to see them as enthusiastic immigrants who very quickly become ideal citizens. They are hard-working and industrious.

Vietnam has had more than its fair share of invaders over the centuries and the Vietnamese have very negative attitudes towards most of their previous enemies. They despise the French who were long time colonial masters; they hate Americans who caused enormous damage, trauma and ongoing suffering as a consequence of American intervention in Vietnam in the 1960s and 70s; they are none–too-keen on the Japanese, Cambodians and Koreans as a consequence of various invasions and many now see the Chinese as the new invaders as China flexes it muscles in the region. Australia? They express no negative feelings towards Australia although they are well aware that Australia was on the American side in the Vietnam War.

Image left: Sculpture at the War Museum, Hanoi, made from fragments of American aircraft.

Vietnam has considerable national pride in its performance in the American War (we call it the Vietnam War). Their numerous war museums are very nationalistic and quite clear about the atrocities committed against Vietnam. The Vietnam Military History Museum in Hanoi has a wonderful sculpture made from the shattered remains of American aircraft shot out of the sky which expresses the Vietnamese view more strongly than any form of words.

We left Vietnam feeling we knew much more about the country and its people than we had before.

Owen Peake
Engineering Heritage Australia

Note: All images in this article are by the author.

Railway Bridge over Eddy Avenue in Sydney

Was this the first reinforced concrete bridge to carry trains in New South Wales?

A circa 1926 composite photo of the Eddy Avenue Bridge which appeared in John Bradfield's paper on "The City Railway" in the IEAust Transactions of 1926. Taken from the roof of a building in Elizabeth St, looking south-east. It shows, left to right: the grand Chalmers St entrance to the new electric train stations at Central; the three spans of the Eddy Ave bridge with an electric train standing on the bridge and a tram exiting from under the central span; the 1906 Central Station building, clock tower and colonnade; a tram entering (or leaving?) the Colonnade over the Eddy Ave tram bridge; the spire of Christ Church St Lawrence; and Daking House, far right. Image: Australian Railway Historical Society, NSW, Railway Resource Centre (ARHS NSW - RRC518363).

Introduction

Reinforced concrete is such a ubiquitous technique for construction in the modern era, that it is perhaps surprising to realise it is a relatively recent innovation, little more than a century old. Certainly cement and concrete were used in antiquity, but the benefits of composite action brought about by embedding steel in the concrete was an emerging technology in the late nineteenth and early twentieth centuries.

For the purposes of this account I use the term 'reinforced concrete' in the modern sense of numerous, relatively small, round bars cast into the concrete, typically near the tension face of a beam. Several other models were used in the development period including expanded mesh and embedded heavy steel sections. In particular the New South Wales Government Railways (NSWGR) were great users of old rail as the source of the steel component of steel – concrete[1] bridges. As in all assertions of 'first' the claim rests on the qualifications imposed. There were certainly concrete bridges which contained a necessary steel component on the NSW Railways before Eddy Avenue. Some were structures which were predominantly arches, relying on a small amount of steel to preclude cracking of concrete under some load conditions. Others used closely spaced (eg 600mm) large steel joist sections, located at mid-height within a concrete beam, or used the aforementioned old rails.

Significantly the NSWGR engineers seemed reluctant to use reinforced concrete for a bridge which carried the weight of a train. A major deviation of the Main Southern Line was constructed between 1916 and 1919 with a large number of arched masonry bridges both over and under the line. Those under the line are brick, those over the line are concrete with old rails embedded.

In 1919 a train-carrying bridge was built in Sydney on an inner city goods line over Bellevue Street, Glebe. It remains in service with a single span of just 4.5 metres, and contains within its rectangular slab, rolled steel joists nearly as tall as the thickness of the slab. It is certainly a steel-concrete bridge, but it is left to the reader to accept or not whether it is a reinforced concrete bridge.

The Development of Railways in NSW

The first railway in NSW was opened in 1855, nominally from Sydney, the capital city (though it was then a small town by any modern measure) to Parramatta – all of 20 kilometres away. The intention of the proponents was to reach across the mountains which surround the city, with trunk lines to Bathurst in the west and Goulburn to the south, and thereby tap rich pastoral lands. These objects were practically achieved by 1875. Separate development had occurred from Newcastle, NSW's second city, 160km north on the coast, and a trunk line had extended north from there. These main trunk lines were quickly extended to reach the borders of the neighbouring colonies – Victoria at Albury in 1881 and Queensland at Wallan-garra in 1889.

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[1] *J.M.S Woore Theory of Steel-Concrete Bridge Construction, Proceedings of Sydney University Engineering Society 1902 p35.*

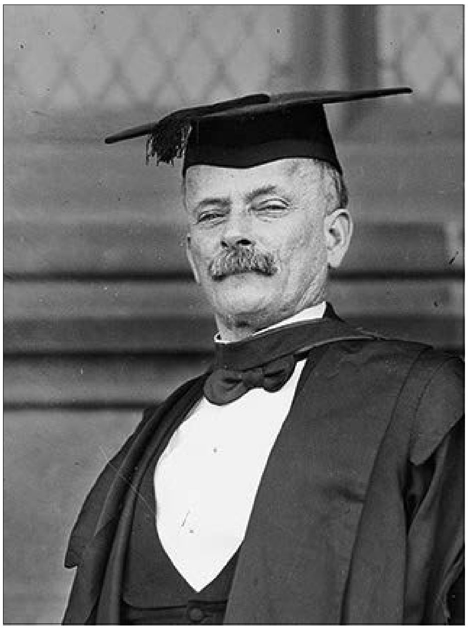
From these trunk lines, branch lines were constructed to serve important towns and sources of traffic. However the then Sydney terminus was never considered ideal. It was too far from the centre of the city. This situation had arisen from the inability of the original Sydney Railway Company to purchase a more central site, and the political difficulty of the NSW Government, who took over the railways before they opened, in diverting funds from country projects, which would open up productive lands and profitable routes, to a project of mere commuter convenience.

Nevertheless the city grew extraordinarily rapidly in the latter half of the nineteenth century and something had to be done. Apart from the commuters who used those sections of the trunk lines closer to Sydney, other commuters could use dedicated commuter lines which had been built during the 1890s. Steam trams had been introduced to the streets in 1879 and these were electrified from about 1899. While many trams served their own routes, a significant proportion of their effort was devoted to the service between the railway terminal station and the city.

A new and grand terminal station (known as Central) was built, and opened in 1906, to replace the grown-like-topsy original terminus, but it was only just a little closer to the city. The issue remained unresolved, despite decades of proposals, enquiries and promises.

John Bradfield, Engineer.

The man who is generally given credit for the creation of the Sydney transport system was John Job Crew Bradfield. He had been born in Queensland and trained at Sydney University, being one of the earliest graduates in engineering. Of course his notoriety and place in history rests with his great bridge – The Sydney Harbour Bridge – but he was responsible for much else, particularly the City Railway, and the whole modernisation and electrification of the commuter network of the wider metropolitan area. Apart from his competence as an engineer, through meetings and newspapers he was the driving force in creating the public expectation and the political will to build these assets for the city.



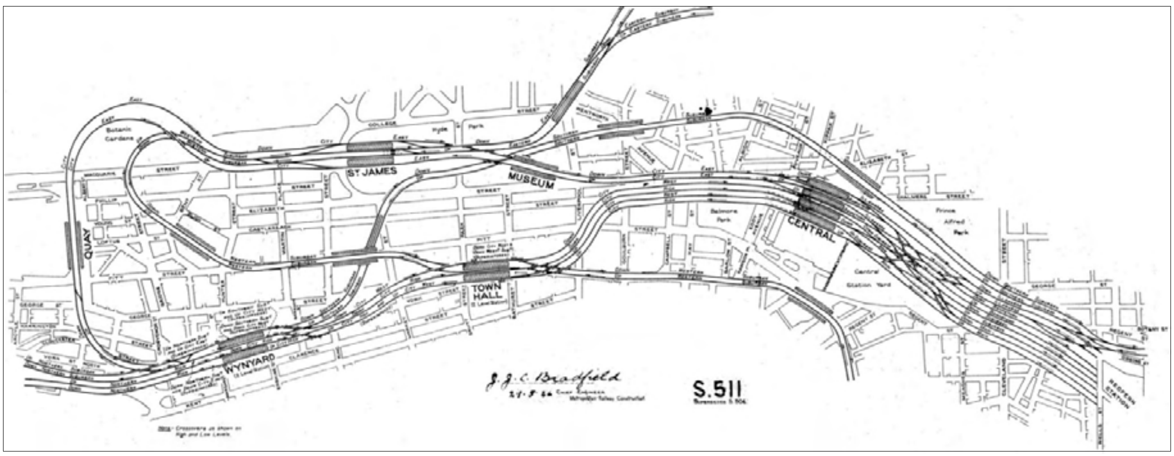
John J C Bradfield, BE(Civil), ME, DSc
Photographed in 1924, on the occasion of his award, by Sydney University, of the distinguished degree of Doctor of Science in Engineering. Image: S U.

He was appointed Chief Engineer, Sydney Harbour Bridge and City Transit in 1912, and in 1914 toured Europe and North America to study large bridges, railway electrification, and methods of tunnelling railways under existing cities.

Upon his return in 1915 he submitted a well-illustrated report which became the blueprint for the work which followed. The broad outline of the City Railway was not his alone. Consensus had emerged over the preceding decades that a loop under the city was the solution, with some connection to a bridge to the northern side of the harbour. Bradfield's tour had shown him that there were two means of building underground railways under cities. A system with tunnels and stations at a deep level meant that routes could be chosen without regard to surface topography or structures, but did impose the cost of long access stairs and escalators for commuters and steep gradients for trains. A design with the tunnels and stations just below the surface meant that access would be better for users, ventilation would be easier, and that some of the work would be above ground and thus cheaper to construct. The cost of the shallow design was the need to deal with all manner of existing building foundations and buried services. Bradfield chose to build a shallow system. Once the decision had been made to cross the harbour with a bridge, rather than a tunnel, he probably had little choice as from a deep tunnel no train could climb to the necessarily high bridge deck over the working Harbour.

Image: Bradfield's 1926 diagram of the proposed City Railway. At left (north) is Circular Quay and the railway approaches to the future Harbour Bridge. At right (south), beyond Central Station are the lines on towards Redfern Station.

Lines branching off at top & bottom are proposed future branch lines to the Eastern & Western suburbs – not to be built at the time.

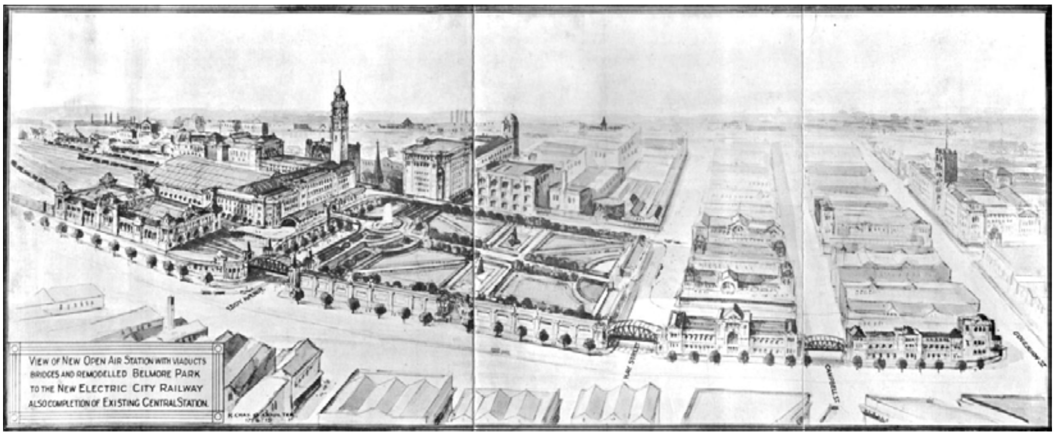


Railway Bridge over Eddy Avenue in Sydney

Thus for the subject of this story – the Railway Bridge over Eddy Avenue – the time had come. The new platforms to serve the city, next to the Sydney Terminal (Central) Station, would be on the surface, approximately at the same level as the existing platforms, and the route towards the city across the low lying area of Belmore Park would be an embankment, pierced by bridges over Eddy Avenue, Hay Street and Campbell Street.

Bradfield's first sketch design, included in his 1915 report, shows the three bridges as steel trusses. The drawing is a little fanciful as the bridges are narrow and insignificant. In reality, even in 1915, all three would have been four tracks wide and thus almost certainly made with at least three trusses. Eddy Avenue is shown as a single span, whereas it was always destined to be longer than that across the wide avenue.

A small amount of work was done on the new railway in 1916 and 1917 but then all work ceased until 1922. In the hiatus Bradfield revised the plans. Four tracks into the city became six, then Eddy Avenue would be built as a seven track bridge. Four or five parallel sets of trusses with one or two tracks between each pair would not be acceptable so close to the magnificently elegant design of the near new Sydney Terminal 'Central' Station.



Bradfield's 1915 sketch shows the new Railway Station at Central, & the railway along Belmore Park. RRC Collection

Bradfield went back to his favoured form of bridge structure – the arch. At least he intended to let the man and woman in the street who viewed this set of three bridges imagine that they were arches. His first problem was their flatness and the lack of road clearance. Eddy Avenue rose to Elizabeth Street as it came east past Central station and there was not anything that could be done to change that. The inbound[2] tramway bridge already in existence over Eddy Avenue was a concrete arch, perhaps with an embedded steel truss formed of retired rails, but at that point the clearance was high. The outbound tramline was a steel bridge but as a single line it was highly decorative and quaint. Seven more of them together, built for heavier trains, would not look so charming.

Concreting the arch over Hay St on 4th March 1924. Electric concrete mixers on platforms over each of the abutments send concrete mix down chutes, while a crane on rails serves a third mixer at street level on Elizabeth Street. Image: ARHS Railway Resource Centre collection.

One means of easing the problem was to raise the level of the new electric train platforms, and the tracks over the Eddy Avenue bridge, by four feet (1.2m).[3] This gave that much extra height below. Hay St and Campbell St bridges, next streets north along the Park, were acceptable as true arches, even if Campbell St has restricted clearance at 3.8m. Both bridges are Monier arches, with significant amounts of reinforcing steel in the form of bars, and thus something of a construction landmark as they certainly carry the weight of trains.

However, Eddy Avenue would still not work as an arch. Bradfield, working with his design engineer Robert Boyd, turned to reinforced concrete to span Eddy Avenue – not to counter the effects of tension in a too-flat arch, but to create a beam bridge which would look like an arch.

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2 Trams operated into the colonnade at Sydney Terminal Station from 1906, entering and leaving via bridges over Eddy Avenue. Although the tramways system of Sydney was closed by 1961, modern light rail has been introduced using the same bridges and colonnade. Trams which used the colonnade originally travelled in the opposite sense to the modern light rail to Dulwich Hill.

3 Bradfield's 1926 paper "The City Railway" *IEAust Transactions*

Railway Bridge over Eddy Avenue in Sydney

To the public eye the Eddy Avenue Bridge would be just a third identical member of a set of sandstone arches supporting the railway across the park. The design Bradfield and Boyd produced, which has claim to be the first reinforced concrete train-carrying bridge on the NSW Railways, is a clever and, after 90 years of constant use, an apparently sound one.

There is one reinforced concrete bridge which could be identified as pre-dating Eddy Avenue, and it is only metres away from that street. The Northern Concourse of the new electric platforms is provided under the tracks, immediately adjacent to the platforms. The roof of that space is strong, to carry trains, and is unquestionably of reinforced concrete construction in the modern sense of the word. If the 'title' of first must be awarded then by what criterion is it to be assessed? Both Eddy Avenue bridge and the North Concourse roof were built at the same time, though one must have been 'finished' before the other, and both came into use at the same moment when the same train crossed both, seconds apart.

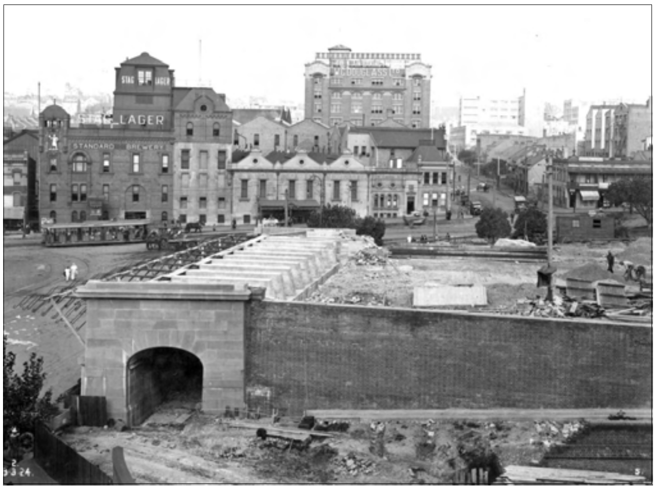
Left: Central Station North Concourse under construction with some of the roof reinforcing in place. 18-11-1924. ARHS NSW - RRC5174919

Right: Concreting of the North Concourse roof completed. Photo 24-03-1825. ARHS NSW - RRC517455

The main entrance to the North Concourse was in Chalmers St (at left of the composite photo at the start of this story). Stairs and lifts were installed so pedestrians could get up to the suburban platforms.

But the adoption of reinforced concrete beams over Eddy Avenue did not alone create the elegant solution which Bradfield sought. It would not look like an arch and with an apparently inescapably great depth near the centre of the spans, as simple beam bridges must have, the clearance problems remained. The answer was found by building a continuous bridge which relied for its spanning capacity as much on cantilever action from the support points as bending strength at mid span.

The wide avenue required a three span bridge over the traffic lanes and tram lines. The bridge could readily be made continuous by pouring the concrete for the three spans on the one day, with suitably placed steel reinforcing bars over the piers and abutments. The centre span would thus be supported by the outer spans and be very strong and rigid, but the outer spans would have nothing from which to cantilever, as beyond them there was nothing but the earth fill of the approach embankments. The answer to this need for rigid abutments was found in the short spans over the footpaths on both sides of the avenue. Although of only trivial span (12 feet, 3.6m) they are reinforced concrete girders as deep as the adjacent road spans. Further, the piers on either side of the footpath are wide and heavy and carry reinforcing bars up from the foundations into the beams of the bridges. They are designed as thoroughly rigid abutments, from which the road spans may well cantilever. With much of the strength of the bridge provided by the deep haunches, the central parts of each span are shallow and a satisfactory road clearance is obtained.



Left: The North footpath span completed. Photo taken 11 Oct 1923. Right: The South footpath span completed. Photo taken 28 March 1924. Note the reo bars projecting from both footpath spans, ready for the roadway spans. These photos probably taken from the tram bridge, both looking east to Elizabeth St. The tiled roof in the foreground above is possibly on a substation for the trams. Images: ARHS NSW - RRC Collection.

So, the three railway bridges – over Eddy Avenue, Hay St and Campbell St – were designed to look like a set, though Eddy Avenue, structurally, is nothing like the other two. The next challenge was to build them. Campbell Street and Hay Street were simple enough projects, though like all civil engineering in 1923, intensively demanding of the muscles of men and the design by the supervising engineers of every procedure in the erection.

Hay and Campbell Streets were each closed for a time, falsework assembled, the concrete arch poured and the road re-opened. This option was not available at Eddy Avenue. The road was too busy to close and worse, it carried a vital tramline which could never be closed. The three span bridge could not be made one span at a time as the continuous design practically required all three to be poured simultaneously.

Image: Erecting a steel falsework girder above the South roadway lane in Eddy Avenue, 5 Feb 1925.
ARHS NSW - RRC-517441

The ends of these girders are resting on heavy timber falsework frames, or trestles, built against the new reinforced concrete walls (or piers) between the south road span and the north side of the tramway span.

At the south (right) end of the girders, the heavy reinforcing projecting from the south abutment (or south footpath span) of the bridge, was completed nearly a year earlier than this work.

Hooked reinforcing rods projecting from the new wall (bottom left) will be built into the reinforced concrete beams when these are poured. In the bottom left corner, the ends of three girders spanning the central tram span are visible.

The cleverness of design and construction engineers in the 1920s came to the fore. The whole seven track wide by three span long bridge was formed up leaving all the road lanes and tramlines open except for brief times. To give one example of those 'brief times', the erection of the steel girders which form the heart of the falsework warrants comment. The girders over the tramlines were erected first, early one Sunday morning, after the trams had ceased for the night. Timber trestles were already in place along each side of the central piers and two cranes, standing in the road lanes, lifted the girders from trucks. The total elapsed time to place the steel girders for the tramway span was just 70 minutes.[4]

Image: View through the falsework under the North road span looking east towards Elizabeth Street.
5 Feb 1925. ARHS nsw RRC-517442

Here we see the falsework girders from below, and the timber trestles supporting them. Behind the trestles on the left is a wall of the footpath, doubling as an abutment at the north end of the bridge.

This photo was taken on the same day as the south road span girders (see above), but the work at the north end is a little more advanced, with timber cross beams in place above the girders.

There is much of interest in this photo. First the street sweeper with his broom & dustpan on wheels – very necessary in the days of horse transport. Beyond him is an old Steam Crane with vertical boiler and all seated on short sections of rail line.

Beyond the crane is the wall of Tooheys Brewery, on the far side of Elizabeth St. Attached to the wall is a little Tram Controller's Kiosk, with a ladder the Controller had to climb to get to work, controlling the switching of all the nearby trams in Elizabeth St and Chalmers St and Eddy Avenue.

[4] Bradfield describes this work in his 1926 IEAust paper.

As if the bridge design was not already sophisticated enough, there was now the issue that the road was skewed to the railway. The reinforced concrete beams, beneath the deck, followed the railway alignment, whereas the timber 'arch' formers were square to the road. Thus these main timber constructions, which define the curve of the lower face of the beam, are truncated. They never reach from one side of the road to the other because they are always intersected by the skew of the railway.

Image right: Looking north-east over the three spans, 13 Feb 1925. ARHS NSW - RRC517446

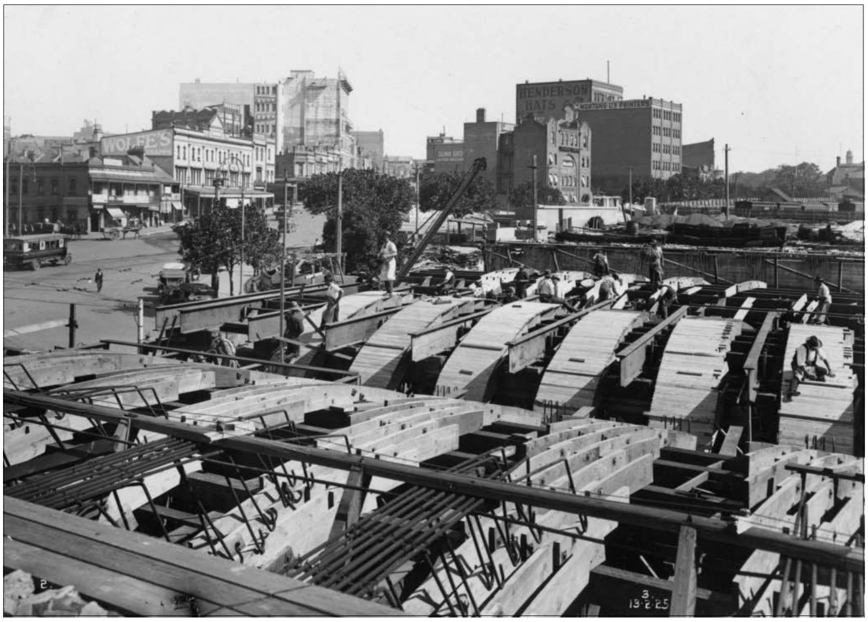


Image left: Looking south-east over the three spans, 19 Feb 1925. ARHS NSW - RRC517448

All girders and beams are in place over all three spans, and carpenters are forming the curved shape of the soffit (underside) of the concrete beams. Trams are free to come and go, but the north road span is closed.

Soon enough however the careful planning allowed this complicated falsework and formwork to be placed and reinforcing bars, which are fundamentally no different to what would be used in a twenty first century construction, were placed.

Image right: View across all three spans of the Eddy Ave bridge, looking from north to south. 24 March 1925.

Steel reinforcing for all the concrete beams across the three spans has been placed. The future depth of the beams can be judged by the two men (at right centre) standing in one of the troughs.

Between the troughs for the concrete beams, formwork boarding for the slab, which reaches from beam to beam, is already set up, and work has started on setting out the steel reinforcing for the concrete slab at the south end.

Reinforcing bars and aggregate for the concrete are stockpiled beyond the south footpath span.
ARHS NSW - RRC517457

Sections of the width of the girders and deck were concreted across all three spans, north to south on the same day, though not across the full seven track width of the bridge as the capacity of the mixing plant and the delivery system could not supply that volume of concrete.

As with all City Railway concrete work at that time, the material was batched on site, using electric mixers. These machines were always carefully placed to allow, where possible, a downwards flow of the concrete to its place of use. At Eddy Avenue however, wheelbarrows had to be used for distribution.

Image right: Pouring concrete near the south end of the bridge. 2 Apr 1925. Bradfield (far left) with Construction Supervisor William Farrow and other officials look on. Stockpiled cement bags have replaced the steel reinforcing bars beyond the south footpath span, and the new train platforms are in the background. Note the tipping barrow with large wheels used to place the concrete. ARHS NSW - RRC51740

Image left: The bridge is near completion. Falsework has mostly been removed from the south span, though some work continues from a precarious scaffold. 14 July 1925. ARHS NSW - RRC517490

The decorative sandstone face presents the distant viewer with the appearance of a stone arch bridge, for the blocks are jointed as if they were voussoirs. It is merely a façade, placed before the concrete and secured in place by that material flowing behind it.

The next challenge was the dismantling of the falsework. Viewed from the street level, between each pair of deep concrete ribs were large steel beams, which had supported the rest of the timber formwork. How were they to be got down? If Bradfield had had a high powered fork-lift he might have used it, but his plant was restricted to a fleet of rail-mounted electric cranes – and some steam cranes – all of limited reach and lifting capacity. He had cleverly left small holes through the slab, above each falsework girder. An electric crane, set up on the bridge deck, lowered each one in turn.

There is ultimately little to be achieved by creating tables of 'first of its type', but Eddy Avenue Bridge stands as a very early example of excellent design and careful construction.

Bill Phippen OAM, B.Sc., B.E., FIEAust

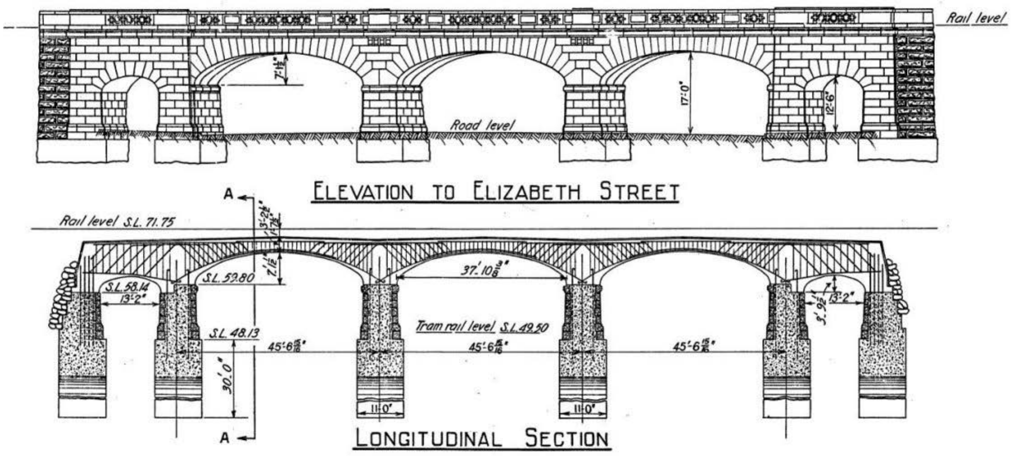


Image right: Eddy Avenue Bridge, from the RRC (Railway Resource Centre) Collection. The longitudinal section diagram shows the massive reinforcing in each span and the abutments.

Connections

Sixth International Congress on Construction History 2018

The 6th International Congress on Construction History (6ICCH) is being organised for Brussels, from July 9 to July 13, 2018 following previous editions, which took place in Madrid (2003), Cambridge (2006), Cottbus (2009), Paris (2012) and Chicago (2015). The Organising Committee warmly invites contributors from all backgrounds associated with construction history to take part in this 5-day event. The program will consist of highly interesting invited key-note lectures and numerous paper presentations, discussing a broad range of topics related to Construction History.

For more information, go to the Congress website at: http://www.6icch.org/index.html

Rapid deployment of a Wireless Sensor Network on the Clifton Suspension Bridge.

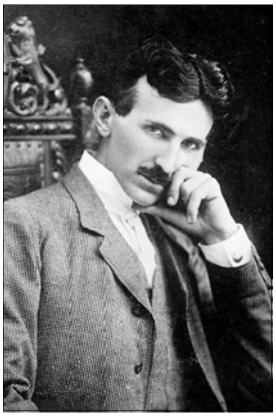
I receive many updates from the ICE of technical papers that are free to download from the ICE Virtual Library. Most are only free for a few weeks, but this one (title above), from *Proceedings of the Institution of Civil Engineers - Smart Infrastructure & Construction, Vol 170, Issue 3, September 2017*, which caught my eye, is open access.

The abstract says: *The Clifton Suspension Bridge is an emblematic* [and very famous historic] *structure in Bristol, UK. In this paper, a rapid deployment of a structural health monitoring (SHM) system for short-term monitoring is described. The system, deployed in a single day, integrates wireless SHM and open-source data management systems to gather valuable information about the bridge use (loading). The deployed system can be used to inform structural response models as well as studies for traffic engineering purposes. The use of open-source software was critical to the successful deployment.*

Find it at : https://www.icevirtuallibrary.com/doi/pdf/10.1680/jsmic.17.00014

We've all heard of Tesla cars, but who knows about Nikola Tesla?

The Age recently reprinted a New York Times story, first published on December 30th 2017 – *Tesla the Car Is a Household Name. Long Ago, So Was Nicola Tesla.* By John F. Wasik. Herewith a few tastes from the story:



A Tesla is an electric car. Just about everybody knows that. But it is less widely known that the car was named for Nikola Tesla, an electrical engineer who was once renowned as the prototype of a genius inventor. . . . In the age of Edison, Westinghouse, Marconi and J. P. Morgan, Tesla was a giant of innovation because of his contributions in the fields of electricity, radio and robotics. . . .

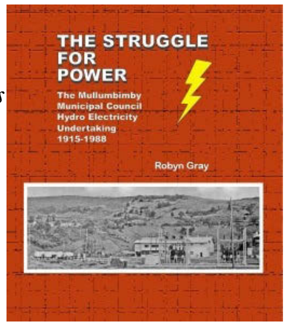
The A.C. Motor: In 1884, Tesla came to New York to work for Thomas Edison with the hope that Edison would help finance and develop a Tesla invention, an alternating-current motor and electrical system. But Edison was instead investing in highly inefficient direct-current (D.C.) systems, and he had Tesla re-engineer a D.C. power plant on Pearl Street in Lower Manhattan. The men soon parted company over a financial dispute. . . . George Westinghouse provided funding for Tesla's A.C. induction motors and devices, which soon came to dominate manufacturing and urban life. . . .

Wireless transmissions: Tesla developed radio technology and tested it from 1892 through 1894. He called radio an "oscillator" through which electricity is converted into high-frequency radio waves, enabling energy, sound and other transmissions over great distances. . . .

See the NY Times story at: https://www.nytimes.com/2017/12/30/technology/nikola-tesla.html

A book by Wasik – *Lightning Strikes: Timeless Lessons in Creativity from the Life and Work of Nikola Tesla* is available at: https://www.amazon.com/Lightning-Strikes-Timeless-Lessons-Creativity/dp/1454917687

The Struggle for Power, The Mullumbimby Hydro Electricity Undertaking 1915-1988



This is the title of a recent book by Robyn Gray of Eureka, NSW. Some of you may remember the story about William Corin and his Mullumbimby NSW Hydro-Electricity Scheme in the March 2015 issue of EHA Magazine. Ms Gray's book *is a chronological tale of how the Undertaking grew from street lights in one town to a fully electrified franchise, supporting lives and commerce, with a number of Australian 'firsts' along the way. . . . the appendices include time line, thumbnail sketches of engineers, generation figures 1926-1960, bibliography/sources and index. There are photos, maps, and original site plan.*

The book is available from Robyn Gray at crg.28716@bigpond.com at a cost of $35 + $10 postage.

Eddy Avenue Bridge in February 1925 (above), and ready for track laying in October 1925 (below).