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Kennedy-Wunsch Lecture 2014

A Chemical Engineer's Role in Design, Operations, Project Management, Consulting and Governance.

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Introduction

Thanks for asking me to present this lecture. It is an honour and I feel privileged to be in the company of my four predecessors - Miles Kennedy, Kevin Marshall, Graeme Robertson and Merv Jones.

Miles Kennedy's inaugural address[1] covered the birth and early development of the chemical engineering profession in New Zealand since the 1920s, and in particular the establishment of Stan Siemon's chemical engineering classes in Canterbury University. Miles' lecture, as well as covering his own personal career, gives some detailed background to chemical engineers of note who passed through Canterbury University, some of whom influenced my own career, in particular Dr Tom Hagyard, whose electrochemistry lectures were a mystery at the time, but later proved invaluable to me. Of particular interest to me in Miles Kennedy's lecture was the data he presented on where Canterbury chemical engineering graduates were employed in the late 1960s, early 1970s. In 1974, the pulp and paper industry, which I joined in 1969, employed 15% of the 250 identified graduates, with the dairy industry not far behind. These two industries were the main choices facing the graduating class of 1969. I chose the former, or rather, it chose me. Some colleagues of mine in the Canterbury Class of '69 who also made careers in the pulp and paper industry were Ken Stuart, Bill Johnson, Gordon Sutton, Stuart Corson, Kit Wilson, Fred Staples, Kevin Kemeys, and the late Peter Sligh.

Before I launch into the key milestones of my career, I should reflect quickly on a few points I gleaned from a review of the other Kennedy-Wunsch lecturers to date.

[1]Miles Kennedy, *"Early Days of Chemical Engineering in New Zealand"*, Kennedy Wunsch Lecture 2010

Kevin Marshall[2] followed Miles Kennedy's inaugural lecture and referred to his "accidental" training as a chemical engineer which led on to a distinguished career in the dairy industry. His work and that of others is well documented in the recent publication, *"Whey to Go"*[3], where he is one of several co-authors. This is an excellent read for all chemical engineers, but particularly for people like me who were vaguely aware of the developments in whey protein ultrafiltration going on in a parallel universe to my own industry over several decades from the 1970s onwards. I will refer later to some parallels with ion-exchange membrane technology in the chlor/alkali industry.

Graeme Robertson,[4] who gave the 2012 lecture, was a colleague of mine in the Kinleith pulp mill and referred to the socialisation of a graduate within industry and the role of the technical and engineering departments in the heavy process industries as a 'nursery' for operations roles. Graeme also had some good notes on human factors and how chemical engineers "think different". Graeme and I were SCENZ committee members together in the early 1980s, and like Miles Kennedy, Graeme went on to become an IPENZ President.

Merv Jones from 2013, was of course from the 'other Class of 69', Auckland Chemical and Materials, and talked about his transition from a research role into an engineering consultancy business - again some parallels with my own career. The presentations of my predecessors therefore make this a hard act for me to follow.

Why Chemical Engineering?

In a somewhat similar circumstances to Kevin Marshall I found myself an accidental chemical engineer. In my final year at high school in Auckland, I was keen on doing a mining degree, but because I could get a larger bursary by living away from home at Canterbury University and the Otago School of Mines had just closed, I headed down to Christchurch. Miles Kennedy was the head of the department, and taught fluid dynamics; Roger Keey taught mass transfer. Tom Hagyard taught electrochemistry and Arthur Williamson thermodynamics, these latter two subjects both failed to catch my interest then and were somewhat mysterious but have both come in handy in later life. Surprising what is to be found in old lecture notes. (I guess Google has it all as well now.) However, my final year interest was

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[2]Kevin Marshall, *"A Chemical Engineer in the Primary Industries"*, Kennedy Wunsch Lecture 2011

[3]John Macgibbon, ed *"Whey to Go. Whey Protein Concentrate. A New Zealand Success Story"*, Martinborough 2014

[4]Graeme Robertson, A Chemical Engineer in the Pulp and Paper Industry", Kennedy Wunsch Lecture 2012

attracted to Maurice Allen's lectures in process control, and controller tuning theory. I was to spend many hours on the analogue computer carrying out dynamic modelling of control loops.

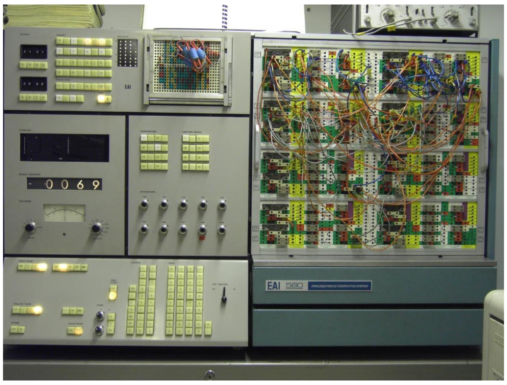

Fig 1 - EAI Analogue Computer)

NZ Forest Products Limited - Kinleith

My final undergraduate year experience in control systems, saw me apply to and be recruited by, Kelvin Chapman, as a Systems Engineer into the Technical Department at NZFP Kinleith. Kelvin had established the Systems Engineering department, and I joined him doubling the team. The Technical Department was where new graduate chemists and chemical engineers all went to learn what their new career was all about.

At the time (early 1970s) civil, structural, electrical and mechanical engineers were generally recruited into what was known as the New Projects Department. This was a large group, peaking at about 150 engineers and draftsmen, tasked with implementing the capital works programme on site at Kinleith. The systems engineering group was not long in existence before both Kelvin and I transferred into this New Projects Department (there being no chemical engineers in this group at the time). My initial tasks were to work closely with the research chemists based in Penrose, Auckland and lead the feasibility studies and project engineering on new bleaching chemical plants which were to supply a doubling of the Kinleith pulp mill capacity in 1973. In particular, I was involved in detailed mass balances for the various chemical supply options to the expanded bleach plants. There seemed to be endless options, but eventually the mill settled on a very high chlorine dioxide replacement of chlorine as a pulp bleaching chemical. (D/CEDED) NZFP was a pioneer in this 'high sequential replacement' bleaching process for long fibre radiata pulp and in the early 1970s was a long way ahead of the environmental push for chlorine-free bleaching of pulp.
This process required an increase in the on-site production of chlorine dioxide from a small 1 tpd batch process to a 12 tpd continuous plant. Chlorine dioxide is a strong oxidising agent, but is highly unstable in the gaseous form and is stored as a dilute solution in chilled water (8-10 gpl).

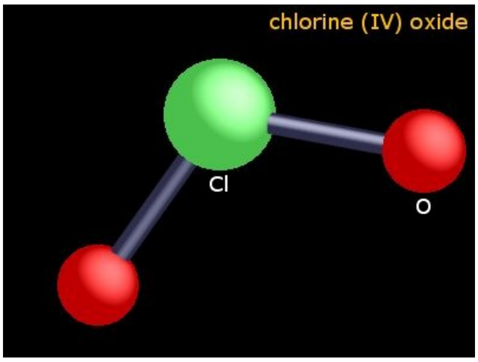

Fig 2 - Chlorine Dioxide Molecule

It is produced by the reduction of sodium chlorate, which had previously been imported from Europe in crystalline form, n 50kg drums but the 20 tpd demand for the new chlorine dioxide production required on-site production by the electrolysis of sodium chloride brine. The newly developed Hooker Chemicals SVP (Single Vessel Process) and sodium chlorate plants were selected and I spent the next two years engaged in the detailed design, construction, commissioning and start up of these plants. It was a steep learning curve, as this plant was the first plant to be built by Hooker Chemicals outside of their commercial scale pilot plant in Michigan USA. I was fortunate to work with a couple of experienced chemical plant piping designers and a Hooker Chemicals commissioning engineer from Canada. The construction phase took place in the early 1970s which was the heyday of strong labour union activity. Robert Muldoon was the Minister of Labour and militant union delegates with names such as Ray Bianchi and Black Jock Mackenzie ran the site.

This project, and a similar plant on the Tasman Pulpmill site in Kawerau, was the first major use in New Zealand of corrosion resistant FRP and titanium piping and vessels. This gave special significance to the project and required a lot of trade training. (Labourers who were used to making surf boards needed to be educated to the wisdom of leaving a hole through the middle of an FRP piping system!)

Fig 3 FRP Piping joints need holes

After the project progressed through construction and commissioning, where I learned lessons which I still refer to today, I transferred into pulp mill operations to manage the facility as a day supervisor. From there I progressed over the next few years to manage the associated mercury-cell chlor/alkali plant, the two pulp bleaching plants and eventually the new kraft pulping line built in 1972.

This period of my career gave me an understanding of how to communicate with non technical people. In general, operating staff in a materials-handling industry such as a pulp mill are semi or non skilled. In my view, communication of complex technical matters to non-technical people is a bigger deal for the chemical engineer than almost every other discipline. Simple concepts (to a chemical engineer) such as the pH scale, liquids with specific gravities greater than 1.0, pressure drops as fluids flow through pipelines, all take on a new meaning when you need to explain it simply and quickly, often in an emergency situation. I learned to apply my controller-tuning skills and systems theory as part of the day-to-day trouble shooting that goes with an operations supervisor's job, sometimes to mysterious glances of operators and instrument technicians.

As part of my wider duties, I also learned how to cope with nights and weekends on the call-out duty roster, shift work and maintenance shut-downs where quick decisions are often required in the interests of minimising downtime, resolving emergencies etc. This is often done with a clear knowledge that you don't have all the facts, but nevertheless must make a quick decision. Often this resulted in revisiting decisions a few hours later with more information.

Softer skills such as shift change protocols and how information is passed from the outgoing shift to the incoming crew were developed, as was an understanding of control room etiquette.

This period also saw my first real exposure to occupational safety and first response to accidents. Chemicals such as mercury, chlorine, chlorine dioxide, ammonia, sodium chlorate, sulphuric acid, hydrochloric acid, hydrogen peroxide were all produced, stored or transported, not always within contained systems. I learned valuable lessons about the impact of a serious harm injury or a fatality on families, the business and colleagues. You never forget.

In the early 1970s, the pulp mill faced serious questions about environmental discharges of mercury from the mercury cell chlor/alkali plant where mercury was used as a cathode. This was (and still is) a major risk with this type of plant. Over a period of years, the population of a small fishing village in Japan, Minamata Bay, suffered severe mercury poisoning as a result of ocean discharges of mercury laden effluent from a chlor/alkali plant located there. The mercury had accumulated in marine life and entered the food chain with long term toxic effects on animals and humans.[5] Publicity surrounding this incident resulted in most such plants around the world eventually closing, but initial steps such as effluent system separation and closure, plant housekeeping and stringent operator hygiene practices were applied at

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[5]Smith, WE & Smith AM, "*Minimata*", London 1975

Kinleith and a significant programme of effluent and atmospheric testing was put in place. The Kinleith mill effluent, after treatment, eventually discharges into the Waikato River, but testing at the time identified the cause of elevated mercury levels in riverbed sludges to be the discharge of heavy-metal contaminated condensates from the Wairakei geothermal power plant. This was subsequently remedied by condensate re-injection into the geothermal bores.

During my time as the chemical plant supervisor (on Friday 13 Dec 1974) one of the chlorine dioxide storages tank failed due to over pressure as a result of commissioning modifications to the pressure relief valve.

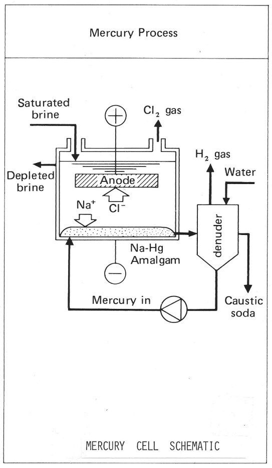
Fig 4 Kinleith ClO2 tank failure

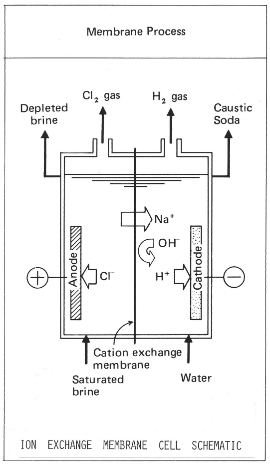
The consequent discharge of toxic chlorine dioxide and chlorine gases resulted in the shut down and evacuation of the Kinleith site for several hours (some 3000 people and many $$$). Time does not allow a detailed explanation of all the learnings from this experience, but the immediate emergency response and subsequent investigation as to the cause and repairs developed my lifelong interest and enthusiasm for HAZOP studies both in the initial design phase and later plant modifications especially during commissioning. This first 6-12 months period is the where almost everything that will happen in a plant's life happens. As a graduate chemical engineer involved in the design, construction and then operation of this hazardous chemical facility, during this period I learnt a lot!

Several years later as part of a visit to New Zealand sponsored by SCENZ, I was fortunate to meet Trevor Kletz, the guru of HAZOP studies, and had a chance to take him sightseeing up Rangitoto Island in Auckland Harbour. We had an interesting discussion about the risks associated with this day in the sun on a not too old volcano.

In the late 1970s, a decision was taken to replace the mercury-cell chlor/alkali plant at Kinleith with newly-developed ion-exchange membrane technology.

Fig 5 Mercury and Ion Exchange Cells





I was seconded back into the project engineering department to manage this project from start to finish. This was another interesting experience and saw me being exposed to a whole new culture. Asahi Kasei had developed ion-selective membranes at their acrylonitrile plant in Kyushu Japan and had built a single plant outside Japan in Canada. They were subsequently to build two facilities in New Zealand at both the Kinleith and Tasman mills.

The non-technical aspects of working with another culture, understanding how they think and react in different situations was interesting (the Japanese approach to contracts and saying "No"). At the start of the project I and two other engineers from NZFP (*Ken Stuart and Dave Kay*) spent three weeks at the project kick-off meeting in a small town in Kyushu where we were the only Westerners. As well as sorting out all the design details, we were immersed in the local culture and history which I have not forgotten.

Following the successful completion of this project, I returned to the project engineering group and used my background in pulp mill operations to assist the early stages of another major mill expansion which took place in the mid 1980s. My time in the pulp mill operations at Kinleith gave me a certain view of external consultant engineers who were hired to support the in-house project engineering teams. I was a fairly frequent user of the phrase "consultants borrow your watch and tell you the time."

Beca Simons/Beca AMEC

But in 1984 my career took a shift to the dark side when I relocated to Auckland and joined Beca Simons as Chief Engineer in a new joint venture company set up to provide services to the expanding pulp and paper industry.
The Beca group and HA Simons from Canada had previously worked together on projects, mainly at the Tasman mill, and after encouragement from the then Chief Engineer at Tasman, John Blackwood, Sir Ron Carter and Tom Simons agreed to establish this joint venture company and recruit staff from within the industry. The vision shared by Ron and Tom was that 50% of a bigger business is better than 100% of a small business, and that there was no reason why a significant portion of the engineering design could not be executed within New Zealand. Paul Potter from Simons Vancouver, an experienced pulp and paper construction manager was recruited to head up the new company, and I was hired as Chief Engineer. This company celebrates 30 years this year, and has demonstrated that the vision was well founded.

Five years after the establishment of the company I took over as General Manager and held this role until recently when I stepped down. Beca Simons (now renamed Beca AMEC following the sale of Simons in 2000) was, and still is a "process and construction driven" engineering consultancy business with a focus on one industry - pulp and paper.

In the formative years we had challenges changing the culture of Beca which at the time was a strong civil/structural engineering firm but light on heavy process industry capability. Based on the Simons culture, we introduced weekly time sheets, tracking design effort by deliverables and multi-disciplinary "squad" checks of drawings. Major project engineering (EPCM) systems and processes were imported from Simons and adapted to local project styles. These are now embedded in the Beca Project Delivery System.

Now is the time to mention the role of the **P&ID** (Piping & Instrumentation Diagram) in design management.

Who reads an engineering drawing anyway?

If you doubt me try it out on the family. Most other engineering discipline drawings are used by related technical disciplines or skilled fabricators/constructors but the P&ID, successor to the PFD (process flow diagram) is owned by a chemical engineer and is the tool for communicating the process logic to everyone.

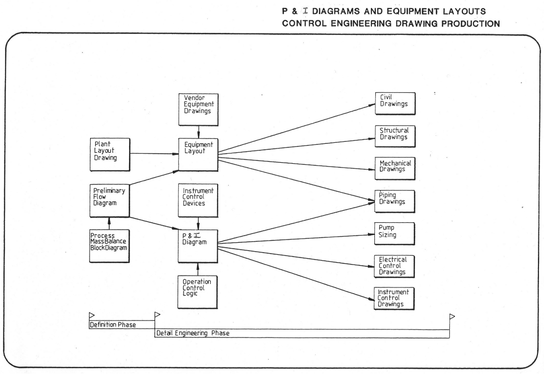


Fig 6 - The role of the P&ID

Once a plant is built, most other drawings are replaced by the physical assets as a means of communication. Not so the P&ID. It lives on in describing the system and how the physical assets are connected and interact and is the key document for operational trouble-shooting and managing change.

Major projects

Over the past 30 years there have been many major projects executed by Beca Simons/Beca AMEC on behalf of our clients in the New Zealand and Australian pulp and paper industry but the following stand out, both from a company perspective and personal recollection.

1987 Tasman pulp and paper mill remediation work following the Edgecumbe earthquake.

1988 PAPRO pilot plant pulping facility at the FRI (now Scion) in Rotorua where the clients were scientists but also chemical engineers.

1989 Fletcher Challenge No 3 Pulpmill Expansion in Kawerau where extensive use of off-site module fabrication gave us design and scheduling challenges.

Fig 7 Tasman CD module en route from Murupara

1991 Carter Holt Harvey Pulpmill Modernisation project, Kinleith, where we worked closely with Bechtel as Project Managers.
1993 Establishment of Beca Simons Kawerau which saw us take over the in-house engineering resources of the Tasman mill and deliver an out-sourced project engineering capability from a Kawerau base. This was a result of the vision of the then mill manager, the late Brice Landman, another Canterbury chemical engineering graduate, who had made a transition from the steel industry to pulp and paper.
1998 Australian Paper's M5 greenfields printing & writing grade paper machine at Maryvale, Victoria. We thought the union muscle in New Zealand in the 1970s was significant until we worked in Victoria.
2010 No 2 Recovery Boiler Rebuild, Carter Holt Harvey, Tasman mill, which was a major maintenance outage critical to the long term survival of the mill operations.

International work

I referred earlier to my colleague Ken Stuart, also from the Canterbury Class of 1969. Ken joined Beca Simons in 1989 as a project manager to lead the major pulp mill development at the Tasman mill. In the mid 1990s when major pulp and paper capital spending in New Zealand slowed down, Ken led our expansion into the minerals processing industries in Indonesia and New Caledonia, particularly for INCO's (now VALE) operations there. This growth in these regions gave us a whole new set of issues to deal with around mobilising staff to spend long periods in Sorowako Indonesia, and setting up in-house French lessons for our New Caledonia work.

Over the years, I have come to conclude that operations staff have the same issues the world over, especially in terms of how they interact with designers and maintenance engineers. It is quite possible to facilitate a successful HAZOP meeting in China, New Caledonia or Indonesia, without speaking the local language.

Final words

Traditional primary and commodity industries are struggling in New Zealand in the face of global competition. Manufacturing and major processing facilities are shifting off-shore so the opportunities for chemical engineering graduates with careers like I have enjoyed are also shifting off shore. There are no longer any large in-house project engineering teams within manufacturing companies, but the role of the engineering consultancy firm has increased and so too has the role of the chemical engineer in such engineering design and project management companies. With this comes increased responsibilities on the process designer. Many major projects are now outsourced to design/build contractors. A lot of detailed engineering is now commoditised/automated eg there is no such thing as a piping isometric draftee, instrument schematic draftee, and this commoditised engineering is often executed in remote lower cost locations. This requires a greater degree of skill in communicating the fundamentals of the process design concepts across cultural and geographical boundaries. How does a graduate chemical engineer learn all the people aspects of an operating facility before they can apply it to the design, construction of a new one?

Chemical engineers usually end up in research, design/project engineering or operations roles in their careers. I have had the benefit of two of these prior to the typical migration into business management and governance. I haven't forgotten the systems approach, an understanding of which is one of the core competencies of a chemical engineer.

For the past five years I have been enjoying a role in the governance of companies in an industry which has been long established in NZ and is part of our country's history - primary food processing and refrigeration. I am currently a board member of Milmeq Limited and Realcold Limited (subsidiary companies of Refrigeration Engineering and Amalgamated Dairies) Through this recent experience I have come to learn how significant a player New Zealand still is on the global scene in this industry. Just like the pulp and paper industry, meat processing plants deal with a widely variable raw material, semi- or non-skilled labour forces, if they can be found at all, a need to focus on Health and Safety, automation and challenging economics. These challenges provide great potential for future generations of chemical engineers.

To end on a brighter note, New Zealand's export-focussed meat, dairy and kraft pulping industries mean that when we develop new processes and technologies here in New Zealand the world listens. These three are all export-focussed industries and New Zealand punches above its weight in all three of these internationally traded products.

Thanks to all my colleagues and staff who have supported me in my career, all our customers who have entrusted their projects to us and finally, thanks to you all for listening.

END