**UC Chemical & Process Engineering - into the new millennium**,
**Design and more.**
Kennedy-Wunsch Lecture 23 May 2022

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I am honoured to be asked to give the Kennedy-Wunsch lecture for 2022 since I've always had great respect for Miles Kennedy and the culture that he developed during his 15 years as the Head of the Chemical Engineering Department at Canterbury. My only knowledge of Sandys Wunsch before this series was inaugurated, was vague; that he was an Englishman associated pre WW2 with lactose production at Edendale. I'm thankful for the information provided by Miles, Kevin, Merv and others about the man.

As many before me have done, I'd like to give you some idea why I came to do chemical engineering. As a farmer's son in North Canterbury I liked building and fixing things and before I started high school I became fascinated by chemistry (eg. that sugar was just a compound of carbon, and water) and I eventually wanted to use chemistry in a practical sense to make stuff. So I read every book about chemistry I could get hold of. In the fourth form (year 10 in modern parlance) I asked a visiting vocational guidance officer what I would have to do to become an industrial chemist. He told me then about a fairly new course at Canterbury College called Chemical Engineering which I could try for and if that proved too tough I could always fall back on industrial chemistry. This would entail, he said, doing maths, physics, chemistry and english through to upper sixth form and then five years at Canterbury. I almost cried as this seemed to me, at the time, an eternity before I could start work. But over the years I guess you could say like Sandys Wunsch I became a chemical engineer by choice and conviction.

After high school I enrolled at Canterbury for the 5 year BSc, BE(Chem). As Miles has already told us the first two years were then the same as for the BE Mech and at the end of that second year Stan asked for the number of students planning to take Chemical Engineering in 2nd Prof. I was most surprised to find I was the only one, as all of the classes ahead of me had had many students; I thought there must be other students away that day. But no, come 1958 I was the only student opting for Chem Eng. Most classes like chemistry and maths had many students but for Chem Eng Thermodynamics I had Rolf Prince to myself and I would go to his office where he often sat with his feet on his desk and regaled me with stories of his Chem Eng experience with Distillers and other places he had worked. It was during this year, I think, that Stan, Tom and Rolf planned conversion classes for students in the year behind me to study over the summer to enable those that opted for it to get a BE(Chem) in four years and finish with me. From memory about 7 chose to go the fast route and four opted to stay with the 5 year degree with the BSc as well. This meant I had fellow Chem Eng students in classes with me for the rest of my degree. Student numbers grew rapidly after this.

All of my final year courses were out at the new campus at Ilam and were in brand new buildings; pure luxury compared to the prefabs on the arts centre site and I really fell for research and design (no thanks to the infamous 5 day exam), enjoying my final year research project on measuring electrode potentials of aluminium so much so, that when Tom asked me to do a PhD, I decided if I could, I would do all I could to attempt this. A potential problem immediately arose. Two years before this I had signed up with Lever Bros NZ with a study award and in fact they arranged my final period of summer practical work at a big Unilever factory in Port Melbourne in Victoria, Australia. Lever's were not interested in my undertaking further study, or gaining a PhD. I offered to pay them back when I could or work for them after my PhD. After some consideration they freed me from all obligations

1961 was very busy for me; I'd started on my PhD in February and a few days after capping for my BSc, BE(Chem)Hons I was married to Joan in early May. John Peet arrived in1961 as a young new lecturer and started a PhD with Stan. Roger Keey followed in 1962 already with a PhD and some experience. Both from the UK. The early 1960s were busy. Al Sacerdote from Cornell completed a Masters in Chem Eng as did our own graduates; Kelvin Chapman, Ian Faulkner, Dave Woodhams and Bill Wakelin. David Woodhams subsequently did a PhD at University of Wisconsin in Madison, Wisconsin, USA and Bill Wakelin, who was President of UC Student's Association, gained a Rhodes Scholarship and went on to get a DPhil from Oxford University.

I had one year full time on my research (with many weeks spent in the Engineering and Physical Sciences library) and then joined the staff as a lecturer, which meant part time research. But I found I enjoyed lecturing in automatic control which I had taken over from Tom and heat transfer which I had taken over from Stuart Smith after he left and went back to Australia. It was particularly gratifying at one graduation to have students say to me how valuable they had found my automatic control lectures. Although as an undergraduate, I had thought that I would finally work in industry, I was finding that I could grow to enjoy this academic life. Many evenings in the week I would come back to the lab after dinner at home (to the chagrin of my wife) to carry out experimental runs without any distraction. (A practice that health and safety might not permit these days). Most of my experimental runs were very time critical, so a checklist was essential as a run was over in 10 msec and any distraction could ruin a run.

Coinciding with the start of my PhD was the arrival of the first digital computer at the University of Canterbury, an IBM 1620. This was only NZ's 3rd digital computer in the country after the Reserve Bank and NZ Railways. This proved invaluable to my doctoral research work and I could not have completed, without it, as much theoretically as I did. I used the computer to obtain numerical solutions to differential equations I could not solve any other way. It also enabled me to obtain the cathodic electrode kinetics for hydrogen evolution on aluminium (exchange current density and transfer coefficient). Likewise the anodic electrode kinetics for aluminium dissolution into aqueous chloride solutions. None of these kinetic parameters had ever been measured before. As a result I became very proficient in FORTRAN.

While I was writing up my thesis I had a talk with Dick Earle who was in transition between Meat Research in Hamilton and Massey University. He had been measuring freezing times on blocks of meat in blast-freezers. He had all the thermal properties of meat measured (specific heats and latent heats of fusion of various fats and muscle tissue etc) and I had been teaching unsteady state heat transfer so I volunteered to model one of his blocks of meat on the computer and solve the partial differential equations for this unsteady state heat conduction. I supplied the results to him and he submitted a joint paper to the Third International Heat Transfer Conference in Chicago. More than a year later, the factory manager at Shawinigan gave me leave to fly to Chicago and present my first paper at an international conference. We did not advertise the fact that the simulation of freezing the block of meat took 3 times the time of actually freezing it. (later desktop computers could do this same simulation in twenty minutes)

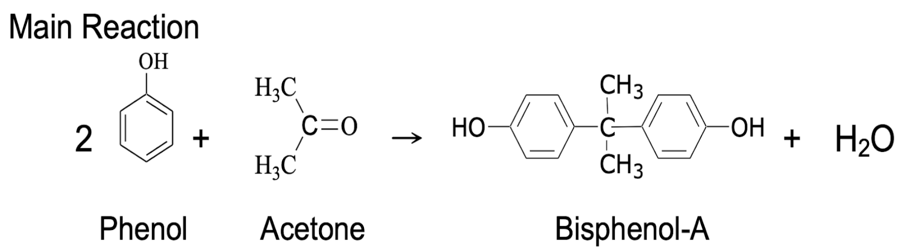
During the last few months of my PhD I learned that Stuart Smith had started a PhD at Canterbury in the 1950s but still had not submitted a thesis. He never did. So in 1965 through an accident of history I became the first person to gain a PhD in Chemical Engineering in a NZ university.  Ivor Watson finished his PhD less than six months later and Ken Kirkpatrick after this.

[I would like to tell you a little story. One morning about six months before I had completed my PhD I came into the lab I was working in with Ivor Watson and Ken Kirkpatrick and asked if one of them could babysit my 2 year old son and one of them could accompany my wife's younger sister, Judith, to a dance we were going to. Ken agreed to babysit and Ivor agreed to be Judith's partner for the dance. About six months later, Judith and Ivor got married.  27 years later their youngest son, Matthew, graduated with a first class honours degree in ChemEng from our Dept.  He then did a PhD  in the US, then worked for nearly 15 years with Air Products Ltd in the US, returned to NZ to rejoin our Dept and is now a professor in ChemEng in our Dept]

**Canadian experience**
**Shawinigan Chemicals Ltd., Montreal, Canada**

Nearing completion of my doctorate, Stan and Tom were encouraging me to get, say 2 years overseas industrial experience and they and I wrote to various companies in the US, Canada, UK and Australia. Some in the US, (eg Shell and Esso) said they would be happy to interview me if I came by sometime. Shawinigan Chemicals in Montreal Canada were happy to employ me for 2 years sight unseen. I found out later from Tom that he knew Dr Sutherland who was Shawinigan's CEO as he had worked with him earlier in the UK. Shawinigan had a major expansion planned and needed a design engineer (chemical); so here I was late in 1965 with wife, Joan and two children, Andrew 3, and Susan 8 months heading off to Montreal to work for Shawinigan.

My prime job initially at Shawinigan was to help design a continuous plant to make Bisphenol-Acetone (BPA)




Shawinigan had three glass lined steel reactors (Pfaudler) which they had been using batch-wise to make BPA. So for continuous operation we turned these into three CSTR in series and did the separation steps in equipment away from the reactors, such as a falling film evaporator to take off the surplus phenol for recycling. To maximise the production of the para isomer of BPA and minimise other byproducts the reaction is carried out with quite an excess of phenol, typically with 10 to 11 mols phenol to one mol acetone so at the completion of the reaction there was virtually no acetone and we have a solution of BPA in phenol. Anhydrous HCl is the catalyst and the byproduct of the reaction is water, not a nice mixture to handle as wet HCl is so corrosive. Hence the glass lined steel reactors, ceramic-lined pumps, QVF glass piping etc. The falling film evaporator to remove the excess phenol from the BPA had zirconium tubes and tubesheet.

This whole plant conversion from batch to continuous took us about 11 months and tripled the production rate and produced significantly better quality BPA. The conversion came in under budget and ahead of schedule. And nobody had done a critical path analysis through the whole exercise!

Following the completion of this BPA expansion I was put onto the team working on expanding the production of phenol and acetone. These are the two chemicals that had started this whole plant site 12 years before.

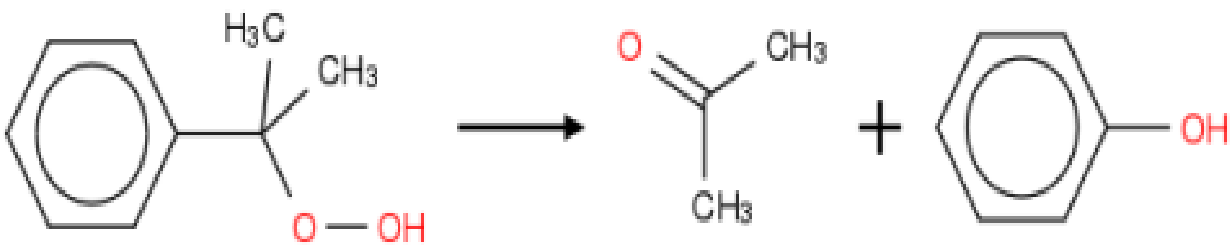
**Phenol and Acetone**

Going back a bit to 1953, Shawinigan Chemicals in Montreal became the first plant in the world to produce phenol and acetone through the oxidation of cumene. They operated under a licence from Hercules Powder and Distillers Co Ltd who held the patents. The plant was sited in Montreal East adjacent to the British American Oil refinery from whom they bought the feedstock, the isopropyl benzene (cumene) which was made there from benzene and propylene.

Within 10 years there were licencees of this process in the UK (BP), Japan (Mitsui), Italy (phenol-chemie) and Germany and Hercules itself in Wilmington, Delaware. These five plus Shawinigan formed the phenol club so far as safety was concerned and always kept each other informed on any accidents that occurred on their sites involving phenol. About a week after we arrived in Montreal I was very shocked reading a report from BP in the UK. This was about a man who was running over the top of open 200 litre drums mostly filled with water but some had an inch or less of phenol on top of the water. He slipped and got one leg wet up over his knee before he jumped down off the drums. He knew this was dangerous, took off his boots and trousers and started washing the phenol off his leg. An ambulance was called but the man died within an hour of his accident. Phenol is a nerve poison and is easily absorbed through the skin.

Cumene has the property that it fairly easily absorbs oxygen from air to form a peroxide, cumene hydroperoxide, which can then quite cleanly split into the products we want viz phenol and acetone.

Cumene hydroperoxide undergoes a Hock rearrangement to yield, with acid catalysis, acetone and phenol




Cumene hydroperoxide Acetone Phenol

A major problem with a process like this is that you must have markets for all your products. You have to sell both products successfully. Alkalie/chlorine plants are the same. Early after the plant startup Shawinigan had plenty of buyers for phenol and a surplus of acetone so they had quite a number of operations where they made 'acetone-derivatives' which increased their ability to use more acetone. Mesityl Oxide and isopropyl alcohol were two but the best of these was hexylene glycol which is easily made from acetone and is an excellent de-icer to add to gasoline for a Canadian winter.

**Back to NZ**

From now on I'll just tell you about interesting items that came up through the next 45 years as most of my time was spent in teaching, research, grading exams or theses, counselling students or applying for grants. Please forgive me if I talk of our Dept you know I mean CU Dept of Chemical and Process Engineering, it has been my home for over 60 years if you count student years.

In early 1968 I was back in NZ busily preparing lectures, finding research and design projects and helping Tom with the final year design class. I also found that Tom had designed a plant for AC Nottinghams Ltd in Christchurch to clean up crude turpentine from Kawerau and Kinleith and make alpha-terpineol for use in the disinfectants they marketed. I was asked to design a distillation column to separate alpha and beta pinene. The beta pinene which was the more valuable pinene was then sold to a Japanese company to make beta pinene resins. The less valuable alpha pinene was still converted to alpha terpineol. This is where I first came across Tissa Fernando who was working part-time as an operator on the terpineol plant while he was a student on his Masters with Tom.

About this time also Don Baker asked me to design a still to produce grain spirit for '45 South' and 'Wilsons' scotch whiskies. Don was a former CU Chem Eng graduate and temporary lecturer for Stan Siemon and was now Technical Director of Greggs and Wilsons' Whisky. I gave him a preliminary design which was a standard cylindrical sieve plate column. I didn't do any mechanical detail, just diam, hole area, plate spacing, downcomer area etc. He came back to me and asked if he could have a square one; he wanted to be able to remove one side of the column for him to inspect the sieve trays for straws or other rubbish! I was concerned with the risk of the gasketting leaking with such a large gasket. In the event that's what he built; the gasket didn't leak and the column performed well, at least up until Wilsons sold out to Seagrams over ten years later.

**Erskine Fellowship**

Erskine Fellowships have been very valuable to Canterbury University; they provide a Department with funds to pay for overseas experts to visit for a month or three or for CU staff to visit overseas institutions usually to advance some aspect of their teaching. Often research interests and conferences can be incorporated.

With Tom Hagyard's untimely death in 1971 I inherited the responsibility of looking after final year design and in 1972 I was awarded an Erskine Fellowship mainly to look at design teaching at selected universities around the world. I also visited Ted Beck who I had been corresponding with at Boeing in Seattle to discuss electrochemistry research on titanium and aluminium. I visited Rice University and University of Houston in Houston, Texas, USA. Here I met with Rudi Motard from whom we acquired our first computer-aided process-design package called CHESS. This package proved to be too difficult to use for teaching purposes. From Houston I moved to the University of Wisconsin in Madison staying with Ed Lightfoot (and family) who had been a visiting Erskine Fellow in our Department in the previous year. My next stop was the ETH in Zurich and then on to Prague, Czechoslovakia, as it was then, where I presented two papers at the Chisa conference. I discovered on the last evening of the conference that I had lost my visa; I think my pocket had been picked on the tram going into the city. The next morning at the Airport the Government authorities would not let me board my flight to Copenhagen in spite of pleas from the Conference organiser. I had first to get another visa, so I went to see the British Ambassador who acted for NZ and she said better not to get them involved as that might add weeks of delay. Relations between Britain and Czechoslvakia were fraught at that time. Luckily I'd met and had discussions with a Czech PhD student, Vratia, who invited me to stay with him and his family and he helped me get photos and the application in for the new visa. His parents were interested in NZ and were amazed that NZ had 70 M sheep and only 3 M people. Tremendous opportunity for the communist party to sign up members his father said. Vratia had limited English and his parents none, so, we played a lot of chess as I spent three extra nights in the country before my visa came through. I phoned my contacts in Denmark and Norway telling them where I was. Because I had appointments in many places in England I cancelled my visit to Trondheim. I had a very interesting visit to the DTH in Denmark which later offered me a home for study leave. In the UK, I visited Bradford, Leeds, Cambridge and Imperial College, London. At Cambridge I was made a great fuss of by John Davidson who arranged accommodation for me in the Warden's flat. It was surprising to find that some universities didn't have any design teaching at all but I won't go into that. From the UK I flew to Japan via Moscow where I met up with Roger Keey at a large chemical engineering equipment exhibition in Tokyo. Following the exhibition we took the Shinkansen (bullet train) down to Kyoto for the first Pachec Conference where we both presented papers.

**Study Leave 1974**

In 1974 I was given 10 months study leave to the DTH (The Technical University of Denmark) and I was awarded a Danish research fellowship. I was working on advanced computer control of a double effect evaporator using a dedicated IBM1800 computer. One could set up any control scheme one wished, all in software from regular PID control loops to the most sophisticated control scheme you could imagine. I ended up developing a system which solved a linear program every half minute, effectively giving us very close to optimal bang-bang control. After working with the snail-paced 1620 and its replacement, the IBM 360 at Canterbury which was now remote, being over in the computer centre, this was luxury to have a computer purely to ourselves. We managed to get our own departmental computer for such tasks about five years later, a PDP11.

**Continuing Education**

One of the duties of a professional engineer is to keep up-to-date and chartered engineers must show on a regular basis that they are doing so. Canterbury ChemEng did its bit for professional development of chemical engineers during the 1970s and 1980s by the collaboration of the Department of Extension Studies with our department. Extension

Studies would survey the market on various topics and we would put together an intense course for in-house 3, 4 or 5 day courses usually with laboratory exercises. Engineers, chemists, managers and others from all over NZ would register for these. Maurice Allen and I ran a very popular 4 day course called "Automatic Control in the Process Industries" a total of 18 times between 1972 and 1988. There were many other courses the Dept also ran. eg. "Drying of Particulate Matter", "Computer Control" and "Micro-computers for Engineers and Scientists".

**1969 The Origin of SCENZ: The National Committee** and start of **The Chemical Engineering Group**

In late 1968, John Pollard as convener, chaired the NZ National Committee of IChemE, consisting of Max Carrie, a chemical engineer with Canterbury Frozen Meat, and myself. John had been in correspondence with John Davidson, then President of IChemE. This resulted in the formation of the Chemical Engineering Group. It was an interesting structure as it was a Technical Group within NZIE (later to become IPENZ and later still EngNZ) and yet was also covered by IChemE, London. Our letterhead had the coat of arms of NZIE in the top left corner and the coat of arms of IChemE in the top right corner. Subsequently the Chemical Engineering Group morphed into SCENZ and later became SCENZ - IChemE in NZ without IPENZ. I've always strongly encouraged graduating students to join IChemE or (NZIE, IPENZ if staying in NZ)

**New Zealand Energy Research and Development Committee, (NZERDC)**

When OPEC increased the price of crude oil from under $3 a barrel in October 1973 to $12 a barrel in January 1974, the political and economic shock was huge. The NZ Govt set up the NZERDC following a meeting between PM Norman Kirk and Dr Colin Maiden, the VC of Auckland University. Very informal. Maiden was made chair of the committee and the other members were Miles Kennedy, Ray Meyer, Dean of Engineering Auckland, Lloyd Brown, chair of National Research and Advisory Council, Jim Hogg, Commissioner of Energy resources, Eddie Robertson, DG of DSIR and David Thom, Deputy chair of the Environmental Council.

It decided early on that its broad policy was to fund contracts that would enable NZ to obtain greater self sufficiency in energy. They would fund contracts for energy research, development and demonstration directed towards meeting NZ's future energy needs. They would do this by using the resources of universities, research associations, consulting groups and industry. The Chem Eng Department gained quite a number of research contracts from the NZERDC for alternative fuels trials, especially using methanol blends with gasoline. Many members of the staff, academic, technical and secretarial, offered their cars for these trials in exchange for information on drivability and the reduction in driving costs that usually resulted. The research students running these trials did all the work of fuelling staff cars with the various fuel mixtures in the trial, recording the results of fuel economy (litres per 100km) and any driveability comments the drivers might have. A fairly new lecturer, Earl Graham and I were managing these trials. The results were generally favourable with improved fuel economy and little or no change in driveability confirming some trials carried out overseas. The reports of these were later sent on to the Liquid Fuels trust Board and became part of the Government' fuel policy.

The NZERDC looked at all areas of energy supply, efficiency and consumption but it had become obvious that NZ's problem was mainly with transport fuels. Some of the success stories from the NZERDC work were passed on to the LFTB for implementation. LPG and CNG were two of these but we weren't involved with this work.

Colin Maiden retired as Chair of NZERDC in 1981 and was succeeded by Ray Meyer. NZERDC continued actively until 1987, when it formally ceased to exist, shut down by a government mini-budget and all its ongoing projects transferred to the Ministry of Energy. Over its 13 year existence it had managed over 460 research contracts and spent under $10 million. Colin Maiden gives great credit to Garth Harris and Ray Meyer for NZERDC's success and once stated "On a value for money basis the research and development output of the committee would be unrivalled anywhere in the world. Its legacy is its reports which provide a valuable database for energy researchers, producers and users. NZERDC also developed considerable human expertise in energy matters in NZ which is also a valuable resource."

**Energy Farming Research Group (EFRG)**

The NZERDC set up the EFRG to assess whether NZ could produce significant quantities of transport fuels from forestry or farming. This group was under the chairmanship of Garth Harris, Executive Officer of NZERDC. The other members of the group were, Mike Leamy, Tom Fraser, Barry Dent, Tom Fookes, John Gilbert, Brian Earl and Nick Brown. Most of these people were connected with agriculture or forestry. I was the odd man out and there to examine processing routes from material produced from the land to gaseous or liquid fuels. Nick Brown was an agricultural economist with the AERU at Lincoln.

This allowed me to employ, for a few months, three of our recent graduates (Russell Burton, Stephen Cook and Ashley Moffat) to work on preliminary designs for fuel plants. The aim was simple; to take various farm or forestry products as feed stocks to produce fuels for internal combustion engines. The processes involved were either biological eg extraction of sugar from fodder beet or starch from corn, wheat or barley or potatoes and fermentation to make ethanol or the gasification of say wood chips or straw to make syngas and then make H2, CH4, methanol or synthetic petrol/diesel. The gaseous fuels were considered seriously because the CNG program was proceeding so well and was especially economically favourable for vehicle fleets where the vehicle was used for many hours per day.

The net result of all of this was that NZ could technically make all of its transport fuels but that the economics were not favourable unless crude oil prices remained very high.

**Bioenergy Developments Ltd. (BDL)**

Arising from the EFRG, Nick Brown and I had become friends and in 1980 we set up a small private company, Bioenergy Developments Ltd to manage any research or development projects we might jointly undertake in this area. The first major project we managed through the company was from NZ Foreign Affairs. This had come from the Government of Vanuatu and was "to examine the feasibility of producing fuel ethanol from cassava on the island of Tanna." Nick and I flew to Port Vila, the capital of Vanuatu to meet with their Ministry of Agriculture people and then flew in a four seater plane down to Tanna, one of the most populated southern islands of Vanuatu. We found when we arrived that their current fuel deliveries, petrol and diesel, arrived on the island in 200 litre drums dumped off small ships and rolled up on a beach out of the sea. We duly presented our report to the NZ Department of Foreign Affairs and the Vanuatu Dept of Agriculture.

Our recommendations for Tanna were that a plant size of 60,000 litre per yr be built initially, expanding to 240,000 l/y over three stages. The economics for E20 looked very attractive. A much larger plant with a capacity of 3 million litre per year was examined for Efate, an island which is larger than Tanna and has the capital, Port Vila, with a population more than twice that of Tanna. The economics were not so attractive as petrol and diesel were more cheaply delivered there.

Bioenergy Developments Ltd (BDL) published a small book called “Fuel Ethanol - a guide for the small scale producer”. The authors were Nick Brown, me and Barbara Smith. Barbara was one of our top graduates from 1980 and had been accepted into the Massachusetts Institute of Technology for a PhD but had some time on her hands before she had to get there for the start of the semester, so BDL employed her to put the book together and write some of the chapters on processing. BDL sold 1180 copies, mostly in NZ but some in Vanuatu, Fiji and Papua New Guinea, USA and Australia. One of our visiting Eskine Fellows, Don Coughanowr, a process control expert, bought 4 copies to take back to the USA. Nick had written a detailed economic section on what a farmer would need to do with whatever feedstock was chosen; wheat, barley, potatoes. I was pretty sceptical that any small scale producer could justify running a small plant unless the feedstock was free/very cheap and he/she was prepared to work for peanuts. But there were many enthusiasts around and if they followed our book and did their own calculations they certainly wouldn’t go into this blindly. (The NZERDC had funded a farm scale plant on a farm near Sheffield on the Chch-West Coast road. This brought home the poor economics of the project.)

I think it is worth mentioning that Miles at this time also employed Barbara as a temporary, part time assistant-lecturer, the first woman so employed in the Engineering Faculty.

**Liquid Fuels Trust Board (LFTB)**

The LFTB was set up by Act of Parliament in October 1978. Colin Maiden was persuaded to become the chairman and Dr Basil Walker, one of our top graduates from 1964, was seconded from DSIR to become its first Technical Director (effectively CEO). It had “a mandate to establish and supervise a program of feasibility studies and trials of methanol-gasoline blends and other liquid transport fuel alternatives based on natural gas.”

Its operation was financed by a levy of 0.1 cent/litre on motor spirits and diesel fuel used in transportation - about $3 million per year. It had become obvious by the late 1970s that the amount of natural gas required for electricity generation had been grossly overestimated. With so much available from the take or pay agreement on Maui gas, Treasury hoped that maybe this should be used to solve the country’s transport fuel needs. It was largely from this LFTB work that the refinery expansion included a hydrocracker and the Mobil process was chosen to make high quality gasoline from natural gas rather than use Fischer

Tropsch to make synthetic fuels from natural gas. It was also from the LFTB work that the NZ Synthetic Fuels Corporation was set up.

**NZ Synthetic Fuels Corporation (SynFuels)**

In 1979 the Government accepted the recommendations of the LFTB and instructed the Minister of Energy, Bill Birch, to negotiate with Mobil Oil Corporation. The Government would initially hold 75% and Mobil 25% of the shares in the company. Colin Maiden became chair of SynFuels. There was a hiatus leading up to the 1981 election because Labour might have stopped the project if they had become the next Government but in the event National just got in and everything proceeded as planned.

Once the project was approved and proceeding it was a very exciting one; it was first in the world, using new technology and important to the country. Construction of the plant was completed at Motonui by the end of September 1985. Within two weeks gasoline was produced that met all specifications. The plant was completed on time and the final cost was $US1218 million, 20%  under the budgeted cost . The plant reached design capacity early in 1986 and NZ became 65% self sufficient in transport fuels. By this time the plant worked perfectly (see below).

I had been invited, over the summer of 1985-86, with a contract from the Mobil chief to help train all the new graduates they had just taken on, 16 in all. They were made up of 9 chemical engineers from Auckland and Canterbury and 4 electrical and 3 mechanical. This didn't mean that I lectured them on anything.  I mainly shoulder-tapped experienced Synfuel staff already working there and got them to talk to the students on various aspects of the plant.  eg.  big 33MW compressors and their controls and characteristics, the cooling water system and its importance to safety.

A couple of matters you don't normally think of when you start a new job are your hearing and facial hair. All new employees had to have a hearing test at company expense and the company keeps a record of this. Very early on employees were warned if they went out on site without the hearing protection available they were at risk of instant dismissal. Beards are not permitted on site, so I had to shave mine off for the summer. The reason given for this is that if you need to use breathing apparatus or have it used on you, you might not get a seal around your face. I observed an interesting standoff one day with a visitor from a government department who had quite a healthy black beard who insisted that he had the right under the law to come on site for this inspection. The Synfuel people agreed that he did have that right but also insisted that he could not do so with his beard on. He wasn't going to take it off. They finally resolved the matter by getting his clean shaven deputy to do the inspection.

I must tell you about a problem they had in these early months of the start up that we solved by some good modelling. If you know the front end of a methanol plant then you know that you have a huge furnace for cracking methane with steam using a nickel catalyst to produce hydrogen and CO. This means reacting steam with methane at >800C. You need about 4 to 1, steam to methane ratio for safe normal operation. If the steam to methane ratio falls below this then the methane can deposit carbon on the catalyst, which is something to be avoided at all cost. So the control system is set up so that if the ratio falls below 4 the plant 'trips' and automatic shutdown of the plant occurs.

Result: No production and a time consuming restart begun. About two weeks before the students and I arrived there had been a 'trip' and then another happened a few days after we arrived. The plant manager was very unhappy as they estimated that a 'trip' cost $3 million.

Looking at the recordings of the steam and methane flows when the 'trip' occurred showed quite oscillatory behaviour. I got one of our recent graduates, Gary Robertson, to build a dynamic model of the steam and methane flow control loops using all the settings as in the plant and control room. The dynamics of these big control valves was second order which made the instability worse. Sure enough we found that the two control loops were inter-acting and too tightly tuned and thus unstable. To achieve stability all we needed to do was reduce the gain on both loops. Luckily Dave Turnbull, one of our graduates from Canterbury in 1972, was the chief Davy McKee Project Engineer and on site, agreed with our simulation and he arranged that the changes we recommended should be made. They were, and the plant didn't 'trip' ie. shut down again from this cause.

With Labour easily winning the 1984 election and oil prices easing back from $40 a barrel in 1980 to $30 at the time of the election the 'Think Big' projects had come under vigorous attack. These projects had become very politicised. Even though over 1986 -1989 average output was about 500,000 tonnes of high quality gasoline per year and operating profit averaged $160,000 per year, the Government decided to sell their share in Synfuels. They gifted their shareholding in Synfuels in 1990 to Fletchers plus $112 million to take the plant off its hands. Surely this was a very bad decision. The two world scale methanol plants at Motonui must have been worth at least $700 million. In 1993 Fletchers sold all of their methanol assets to Methanex for about $1500 million. I'm sure Colin Maiden was very unhappy at this unnecessary loss of tax payers money engineered by the sale and providing Fletchers with a huge profit.

**Davy Mckee Pacific Propriety Co Ltd. 1982-83**

In 1982 I was given study leave to work for Davy Mckee Pacific Proprietary Ltd in their Melbourne office. They had hired me mainly to work on computer-aided-design programs to help them on their large Moomba field contract in Central Australia worth over $A1200 million. I was quite surprised to find that Davy had 10 PhD graduates working mainly in the Melbourne office as well as dozens of other engineering graduates.

I made some significant improvements in some Davy McKee Design packages used for specific design. One of these was developing a computer-aided-design tool "DCOMP" for their major project on the Moomba field in central Australia. This was for calculating pressure drop and phase condition for multi phase hydrocarbon flow in the pipe lines from the Moomba field in central Australia out to the coast near Port Augusta. This had a full thermodynamic package attached for all of the components in the stream. Two other packages I made significant improvements to were:- 1) A Pinch technology program which we called "Extrain", for heat exchanger network optimisation (that was very profitable for Davy) and 2) A coal washing program we called "Superwash" which was used extensively by the mining section of the company. "Extrain" was the Davy in house equivalent of Simulation Sciences package called "Hextran"

Another benefit to me and the Department from this leave period was my experience with PROCESS, a computer-aided process-design package from Simulation Sciences in

California. Davy had a full commercial licence for this and we subsequently used an academic version in the Dept at Canterbury in our final year design teaching.

**WRONZ - 1983 - 1997**

In 1983 the Minister of Science and Technology appointed me a director on the board of the Wool Research Organisation of New Zealand (WRONZ) where I served for 14 years, the last six years as deputy chair. By 1987 the government had stopped making Ministerial appointments to such bodies but the WRONZ Board continued my appointment year after year. This was a particularly interesting board to serve on since it wasn't too demanding, the projects they were working on were interesting and innovative and many of the WRONZ employees were graduates of our ChemEng department.

**Manufacture of pesticides in New Plymouth - 1986**

In 1986 the Minister of Health appointed me to a committee of three for a ministerial enquiry into manufacture of chemicals at IWD, New Plymouth. The tribunal chair was Prof Geoff Brinkman, retired Dean of the Otago Medical School. The second member was Prof Richard Matthews who was a Professor of Cell Biology, Auckland University who was an expert in cancer. This was a very interesting experience in that the real reason for the tribunal seemed to be public pressure to stop 2,4,5,T being made in New Plymouth.

NZ at this time was the only country in the world making 2,4,5,T and the dioxin that is co-produced and this association with Agent Orange used in the Vietnam war, was reason enough to get rid of it in the opinion of most NZers, especially those living downwind from IWD. NZ farmers did not agree as it was a very good cheap herbicide for killing gorse and other brush weeds. One farmer appeared before us and said if he felt he was getting a touch of asthma coming he would spray and that fixed his asthma. We found that there was little or no research on 2,4,5,T use in NZ nor of farmers or others exposure to dioxin from its use so the tribunal set up a number of measures to be taken from blood samples from farmers, spraying contractors and IWD employees. NZ 2,4,5,T was very low in dioxin at 5ppb compared with agent orange at 2000 ppb.

We invited submissions from interested parties including the public, residents of New Plymouth, GPs, farmers, spraying contractors and received about 170 in all. George Hooper gave an extensive submission on behalf of SCENZ. Initially we found a huge deficit of information so we instituted a research program to be funded by IWD to study the pharmacokinetics of 2,4,5,T in users and IWD workers and the sources of contamination they were exposed to. This involved analysing bloods and urine samples from farmers/sprayers and IWD employees. 2,4,5,T is eliminated from the body within a few days, certainly down to zero within a week. The initial surprise was that many of these people had 2,4,5,T in their blood when they hadn't used any spray for 4 months. So they were being contaminated from their living environment.

Other sources of dioxin were examined. The EPA in the US has long been concerned about municipal waste incinerators as high temperature combustion with chlorine present produces dioxins. Even your woodfire will do so if you are burning driftwood from the sea with salt in it. Of more concern for NZ was the use of leaded petrol. In Sweden Dr Stellan Markland had measured the dioxin produced from burning leaded petrol in Sweden's internal combustion fleet. Leaded petrol always has chlorocarbons added to remove the lead from the engine so the dioxins are produced from burning the chlorocarbons at high temperature in the cylinder. Using his data for Sweden here in NZ showed that NZ, at that time, was annually spreading about 38 gms of dioxins throughout the country, mainly in the cities. 2,4,5,T use, at that time, in NZ was annually spreading about 3 gms of dioxins, mainly rurally.

Within a year of our final report, IWD stopped manufacture of 2,4,5,T. and started marketing Escort (read triclorpyr) which contains no 2,4,5,T or dioxin. NZ very soon after this, also phased out lead in NZ petrol.

**Head of Department 1989 - 1998**

In 1988 I was elected to become the Head of Department at Canterbury for a term of five years. At the end of this term I was reappointed for a further term. Over these 10 years we had more changes of staff than there had been over the previous 20 years. This came about much earlier than I might have expected because Arthur Williamson who was appointed Head in 1985 chose to take early retirement to concentrate on his excellent solar panel company, “Thermocell”. Jim Stott who had been with the Dept from 1965 had retired in Feb 1988 and the Department had not been permitted to replace him. In these days employees had to retire at age 65. Even with Arthur’s retirement we were only permitted to replace him at the lecturer level and Chris Williamson (no relation) joined the staff. In 1993 Miles retired and was replaced by Ken Morison. In 1994 we held a very successful Seminar celebrating 50 years of the Department’s existence when Stan Siemon, Rolf Prince and many former graduates attended. In 1995 we had the untimely death of Peter McElroy who was replaced by Ken Marsh. In 1997 Roger Keey chose to retire and Maurice Allen left for greener pastures in Murdoch University in Perth, Australia. Maurice was replaced by Peter Gostomski from Lockheed Martin, USA, and Roger by Lawrence Weatherly from University of Belfast in Northern Ireland. This was the first appointment in 20 years where a full professor was permitted to be replaced by a full professor. After I retired from the headship, Lawrence became HOD as this had been a condition of his appointment.

**Biodiesel Plant 2006**

After official retirement from the University I did more consulting for NZ and Australian companies and still helped from time to time with Design in the Department when I wasn’t visiting Cornell University in upstate New York. (see below). I should tell you of a major project I got involved with on biodiesel for Tissa Fernando, CEO of FloDry Engineering Ltd and one of our most entrepreneurial graduates. He was the Kennedy Wunsch lecturer in 2016.

Tissa, with his research chemist, Praveen Bhagat, had been working on a process to esterify tallow with methanol in the lab using a small (15mm diam) glass column and asked me to design a pilot plant for him to get more data. My first effort was judged too small to build (it was 100 mm in diameter) so we increased the size until Ken Yong, his mechanical engineering design expert, said that it was big enough. At 450mm in diameter, this really was more a demonstration plant (not a pilot plant) in that it could produce up to 600 litre per hour of biodiesel. In 2006 we secured a provisional patent on this reactive distillation column in the names of P Bhagat and WB Earl.

**In Conclusion**

I am still strongly of the belief that Process and Plant Design is the Capstone course of any chemical engineering degree as it compels students to work together to a common end. Working with other engineers is essential. It brings together everything the student has learnt in all her/his other courses with all the compromises that must occur between not just with different plant items but also with plant costs. Tom Hagyard and I put strong emphasis on design projects of significance to NZ and the Department built up a wealth of knowledge over many years. In the early days these were often small plants for the NZ economy alone as the economy was so closed but after the NZERDC came and went we also considered world scale plants where NZ might have a specific advantage. At one stage we found one of NZ's largest companies was secretly copying our students' design reports over the summer. From then on we had the students insert a legal disclaimer at the beginning of their report and we charged the company for their copying.

Over eight semesters between 1995 and 2014, mostly after I had retired from Canterbury I became a visiting Professor in the School of Chemical and Biomolecular Engineering at Cornell University, Ithaca, New York, mainly teaching design. Cornell had a very similar culture to Canterbury and Professor Bob von Berg from Cornell had visited Canterbury five times in the same role, over twenty years.

Over the years, I have made a point of talking to maths and science classes at girls and co-ed schools to encourage female students to consider Chemical Engineering as a career as it has many advantages over typical careers for women. In the 1990s we achieved many classes with close to 50% female students.

In working with Chemical Engineering graduates from Universities in Canada, Australia, the UK and USA, I think I can fairly say ours are as good as the best.

I've always been proud of our graduates as they have gone on to become successful in their subsequent careers and I have named a few of them in my talk above. But there are dozens of others. One of our graduates from the 1980s, Andrew Livingston who is a Professor of Chemical Engineering in London has been made a FRS in the UK, a very rare honour for a NZer.

Finally, I would like to express my thanks to:-

- Miles, who read through a draft of this talk and made comments and suggestions
- Danielle and the SCENZ-IChemE board for inviting me to give this 2022 Kennedy Wunsch lecture.