Kennedy-Wunsch Lecture 2011

Presenter: Kevin Marshall
A Chemical Engineer in the Primary Industries

Why Chemical Engineering?

It is an honour to be asked to give the second Kennedy-Wunsch lecture. Donald Sandys Wunsch, as the Managing Director of the Lactose Company, was engaged in developing profitable uses for whey, which is the liquid remaining after the making of cheese and casein from milk. I spent the major part of my career in the dairy industry in a similar endeavour so it is perhaps fitting that I have been invited to give this lecture.

Sandys Wunsch was a chemical engineer by choice and conviction. I became a chemical engineer by chance. In a conversation with my fellow 7th formers at Christian Brothers High School in Dunedin I said I was going to do a Bachelor of Science degree. “What do you want to do that for?” retorted Brian Hoult, “you’ll finish up as a school teacher! Do chemical engineering, you’ll get two degrees, not just a bachelor of science but also a bachelor of engineering.” It was radical enough for my family that I was even thinking of going to University let alone leaving home and embarking on a five year course. I didn’t even know what chemical engineering was. But Brian said it was good and he had an uncle who was chemical engineer so it must be right.

So chemical engineering I did, as did Brian Hoult.

Intermediate Year

I spent 1959 at Otago University completing the intermediate course.

During this year I had my first contact with chemical engineering, although I did not realise it at the time. I had a part-time job at a tannery in Green Island, just out of Dunedin. Most of my work was in the laboratory. But I learned much about what was an effective but quite basic process of mixing, washing, chemical reaction, diffusion, drying and so on.

I spent many of my vacations during university working at that tannery earning the money to pay my way. In the last two years I rendered all the fatty wastes from the hides and pelts using an open, jacketed kettle, the unit operation of decanting. The conditions were primitive and OSH would have had canaries if they had ever visited.

Canterbury University

When we arrived in Christchurch in 1960 we learned that the Engineering School was shifting. After one term in town, we moved to what was a rather bare site at Ilam. The lecture rooms and laboratories were certainly much improved though.

1960 also coincided with the change in the length of the chemical engineering course from five years to four. So I missed out on the BSc after all.

I enjoyed my time at Canterbury University but I do not intend to dwell on it other than to relate a couple of incidents.

We worked very long hours, including a three hour laboratory on Saturday mornings. One of these laboratories was measuring the heat and mass balance over the Department's boiler. I well remember the lecturer Stuart Smith's comment on our report, "You are scratching about for BTUs like old hens" – he was not impressed by our reasons for a lack of closure in our measurements.

Professor Stan Siemon was Head of Chemical Engineering and Dean of the Faculty. It was not till many years later that I learned of his efforts to develop chemical engineering education in NZ. But while he was undoubtedly a great pioneer in this, he could not excite me with his lectures on statistics. In fact I gave up when it came time to preparing for exams and decided, after looking at past papers for 2nd pro chemical engineering, that I could skip the one question on statistics. Imagine my horror when I opened the exam paper to discover not one but three questions on statistics; I couldn't even define and calculate a mean and standard deviation. This left me with no choice, and given that I could not understand one of the other questions, I am convinced I failed that exam. I was surprised when I was awarded what I considered to be a generous C.

Later, when I started my research career I became very interested in statistical design of experiments and realised I was even designing my experiments so I could use sophisticated statistical techniques. So perhaps Stan did me a favour after all.

That second professional year culminated in one of those events which I found life changing. It was traditional at that time for BP to offer vacation employment (approved practice) to one student from a science or engineering department from each of the Australian states and New Zealand. I was fortunate to be offered that employment and spent 3 months at BP's refinery at Kwinana, south of Perth. BP flew me from Christchurch to Perth, first class – my first ever flight in a plane! They also paid more generously than any approved practice then available in New Zealand.

BP took this exercise very seriously and the group of eight students was given a very impressive induction programme, including detailed explanations of all the processes. We were able to clamber about distillation columns, absorption towers, cracking plants and such like. This more than anything else gave a real feel for what chemical engineering was about.

I investigated the Stretford Process for converting sulphur dioxide from refinery gases into elemental sulphur, an invaluable experience in commercial research, design, costing and report writing.

Job offers

In January 1963 I had three job interviews, all timed so I could do them in one trip – by train from Dunedin to Christchurch, overnight ferry to Wellington, train to

Palmerston North, bus to Hawera and back to Palmerston North then train to Hamilton.

In all three places I was interviewed by chemical engineers:

- At the Lactose Company in Kapuni I met three chemical engineers, Alex Holmes, Jack Dryden, and John Woods. They had been associated with Sandys Wunsch, and had gained Associate Membership of the Institution of Chemical Engineers by the examination route.
- At the Meat Research Institute in Hamilton I met Dick Earle who was later to be my PhD supervisor;
- And at the Dairy Research Institute, now the Fonterra Research Centre, in Palmerston North I met Don King.

Both the Lactose Company and the Dairy Research Institute offered me jobs – I've never asked Dick why I wasn't offered one by the Meat Research Institute; a fellow graduate, Keith Fleming, took that role.

The Lactose Co offered the higher salary ₤1100, ₤60 more than DRI. But my fiancée pointed out that it would be more difficult for her to get a position as a nurse in Kapuni than in Palmerston North. So the Dairy Research Institute it was, probably influenced as well by the opportunity to go overseas on an Institute Fellowship.

I had no idea about chemical engineering in the dairy industry; none of the problems and examples we were presented with during our undergraduate time was derived from the food industry.

The Dairy Research Institute was undergoing change so it was a good time to start there. Kelvin Scott had joined in 1948 to set up an engineering department. Kelvin recruited a chemical engineer, Don King. Don later became Head of Engineering and employed two more chemical engineers, Selwyn Jebson and Graham Latimer.

In 1960 the Institute Board had agreed to extend the Institute's work so as to develop new or diversified dairy products and not just work on the traditional butter and cheese. It was agreed that additional staff and improved laboratory and pilot scale facilities were needed. Of the nine new graduate staff taken on about that time, three were for the Engineering Department. Don targeted chemical engineers. Dave Woodhams and I and, later, Ken Kirkpatrick were recruited.

The unique arrangement was that the new recruits would be given Institute Fellowships to study for higher qualifications or to acquire further skills and return to the Institute when the new laboratories were available in two to three years time. I went to Birmingham University for an MSc in Biological Engineering (would now be known as Biotechnology), Dave went to Wisconsin for a PhD in spray drying, and Ken stayed at Canterbury to complete a PhD in electrochemistry of aluminium under Tom Hagyard.

This Fellowship programme recruited some 20 fellows over the ensuing years. It was later followed by the very successful Dairy Industry Graduate Training Programme.

These programmes provide a valuable lesson for today about successful methods of recruiting, training and keeping new recruits in an industry.

Induction into the Dairy Industry

During the six months induction period before I went to Birmingham, among the projects I worked on was the rate of cooling of blocks of butter in the then new cardboard boxes. Calculations were done laboriously with slide-rule and logarithm tables. Not for us the luxury of computer based spreadsheets.

During this period I was able to see the early experimental development of continuous cheesemaking equipment which eventually became the Cheddarmaster, a forerunner of the equipment which was used throughout much of the world where Cheddar-type cheeses are made.

I was also able to observe the testing of continuous buttermaking machines imported from Europe and modified to suit New Zealand conditions. These quite quickly replaced the wooden and stainless steel batch churns then being used throughout the New Zealand industry.

Dave Woodhams and I spent some weeks visiting many dairy processing plants in New Zealand. This gave us a useful insight into the many unit operations being used to manufacture dairy products.

Birmingham

Birmingham University was a wonderful experience.

In 1956, recognising the importance and potential of chemical engineering for biological processes, the Birmingham Chemical Engineering Department had appointed Norman Blakebrough as head of the new Department of Biological Engineering. Norm had come from industry and was a very knowledgeable, enthusiastic and pragmatic biotechnologist. He was to become a life-long friend.

Don King was interested in continuous fermentation to produce casein by bacterial growth in milk. He reasoned that the Biological Engineering course could provide some useful insights.

I joined four others on the MSc programme. Our course subjects were biological engineering, biochemistry, microbiology, and chemical engineering mathematics. We also had a three month research project. Mine was on the production of yeast by continuous fermentation of cheese whey.

The course included site visits to a number of biotechnology industries. At the brewery where they were experimenting with continuous brewing, which had been recently commercialised in New Zealand, I was the odd person out in the taste tests because I could easily pick the continuous brew!

Another site visited was the Defence Forces facility at Porton Downs. While much of the work there related to chemical warfare to which we were not privy, we learned much about the theory and practice of continuous fermentation and the design of fermenters that could be operated under sterile conditions for a long time. This information I used in my research project at Birmingham and later for my PhD studies.

Whey Processing

I returned to the Institute to find a pilot scale spray drier and evaporator had been purchased. These were first used on demineralised whey powder being produced on a pilot scale ion-exchange plant designed by the Dave Woodhams and installed in the old Taikorea Cheese Factory.

I continued my work on yeast production using continuous fermentation of whey but on a much larger scale than in Birmingham. The workshop at the Institute did a great job in converting an old pressure vessel to a bottom agitated fermenter using a design from Porton Downs. Other unit operations used in that project included plate and frame filtration, centrifugal concentration and roller drying. The product, particularly when co-precipitated with the whey proteins, had a nutritional profile ideally suited for chicken feeding. Some successful trials were undertaken at the Poultry Research Institute, but the product proved too expensive to commercialise.

I also helped develop a product from the acid hydrolysis of casein. This was a dairy alternative to soy sauce. Again there was very limited commercial production but I learned a lot about materials of construction under very acid conditions including glass-lined steel vessels.

A few years after returning from Birmingham I started my PhD. Dick Earle was my chief supervisor. My project was the continuous fermentation of casein whey to produce lactic acid as a means of waste disposal. We had decided by this time not to look further at continuous fermentation of milk to produce casein – we could not stop the shattering of the precipitated casein into very fine particles.

Ultrafiltration and WPC

In 1969 we started on a fascinating journey – the production of soluble whey protein, something at the time not achieved on a commercial scale. A large multinational beverage company (MBC) approached the New Zealand dairy industry seeking a supply of protein with which to expand their range of beverages. The protein had to be soluble at low pH (< 3.5) in the presence of significant concentrations of citrate and phosphate and remain in solution for a shelf-life exceeding a year. MBC had identified that whey proteins had the required characteristics.

However the dairy industry had no experience in processes which would produce a soluble form of whey protein.

Dave Woodhams, at this time completing his PhD in Wisconsin, spent a very hectic time in the US investigating potential technologies and recommended the use of ultrafiltration.

Ken Kirkpatrick undertook some early trials with a laboratory scale ultrafiltration cell and showed it was possible to concentrate the protein in the whey solids and produce a soluble whey protein concentrate.

In 1970 the industry purchased a tubular ultrafiltration plant from Abcor Inc, a company based in Boston Massachusetts, staffed with a number of very competent chemical engineers. The ultrafiltration plant was installed at NZDRI where we had all the equipment to receive milk, make casein or cheese and collect the whey. At that time we had the largest ultrafiltration plant on whey in the world (30m2). NZDRI was right at the leading edge of the technology and over the next few months much was learned about that technology. One Abcor executive was to say later that if something was going to go wrong it will go wrong at DRI!

Ken spent time in Brazil at a pilot plant developing similar product for MBC.

My PhD was the lowest priority project on the NZDRI list and, when more resources were needed, I joined the ultrafiltration project with an early task to investigate whey pretreatment to remove suspended material. This required the installation of self-desludging centrifuges and diatomaceous earth filters.

Within 9 months the team was able to produce on the NZDRI pilot plant a product then known as Solac, which met all of MBC's requirements. The decision was taken to build a much larger plant. This was installed at the Waitakaruru Branch of New Zealand Co-operative Dairy Company. The next 18 months was a time of intense development activity, huge excitement and many frustrations.

Eventually semi-commercial quantities of Solac which met all of MBC's requirements were manufactured.

Meanwhile NZDRI, with a special grant from NZDB, had obtained a range of different ultrafiltration pilot plants – tubular, plate and frame, flat leaf and hollow fibre (spiral wound was to come later) – and these were tested side by side to determine their individual characteristics. Stages-in-series, continuous processes subsequently replaced the batch processes. Pilot plant for ion exchange and electrodialysis demineralisation of whey were added to the unit operations at our disposal.

I was to find out much later that the Lactose Company had a parallel, simultaneous project developing ultrafiltration to remove protein from whey prior to concentration and crystallisation.

During this phase I spent 10 weeks in Europe and the USA visiting whey processing facilities. Unremarkable today, but in 1971 it was unusual to have such an opportunity to travel and see what the rest of the dairying world was doing with whey.

About this time, MBC decided that it was going to take an alternative route to providing nutritional beverages. The New Zealand dairy industry team had undertaken the ultimate in development – a new, unique product for a new application using a new technology. The industry had developed what was undoubtedly the most comprehensive knowledge of whey ultrafiltration in the world. But we had no customer.

It was to be another two years of extensive scientific study and development before an alternative use was found for the whey protein concentrate – initially the pumping of hams. Many other uses followed after that.

For a number of years New Zealand led the world as the only supplier of technically advanced whey protein concentrates for many uses. Even today Fonterra remains a major source for the most technically demanding versions of the product.

The development we started in 1969 resulted in the transformation of a waste product – whey – into a range of valuable ingredients. These whey products and a wide range of other dairy products made possible by membrane processing and the industry's knowledge of protein chemistry and functionality are now worth in excess of $1 billion in exports each year.

It had been a stimulating and, eventually, profitable ride.

Other Process Engineering in the Dairy Industry

I have dwelt on the development of whey protein concentrates at some length because I believe it is typical of long term process engineering developments in the NZ dairy industry and which continue today.

At the recent NZ Institute of Food Science and Technology Conference, Andrew Fletcher of Fonterra's Research Centre spoke of the rich heritage of science and technology which had helped build processing in the NZ Dairy Industry.

Fonterra is the largest milk processor in the world. It has taken every single dairy technology to scale. It has four of the largest spray driers in the world – when I joined the industry the largest plants then were producing 2.5 tonne per hour – large driers today produce that much powder in 5 minutes! The NZ industry also pioneered instantised milk powders.

Andrew spoke about the development of large plants to produce anhydrous milkfat – a technology that eventually lead to the production of spreadable butter, another world first developed in NZ.

The early labour intensive cheesemaking process gave way to continuous processing on equipment developed in NZ, the Cheddarmaster.

In more recent times Fonterra has developed alternative processes for cheese-making and now for example has a plant producing IQF mozzarella direct from milk – a process which previously took 6 weeks to develop a customer-ready cheese is now taking 6 hours.

Separation processes have been developed to a high degree of sophistication – as noted earlier whey protein concentrates were developed in the 1970s. This lead to milk protein concentrates and whey protein isolates in the 1990s.

At Tuamarina north of Blenheim, a reverse osmosis plant concentrates milk before transport to Clandeboy, 450 kilometres away south of Christchurch. This reduces the number of tanker trips by 3000 per year. Even more remarkably, the Tuamarina plant is managed by a control room in Clandeboy. Such efficiencies are also reflected in the automated warehouse technology and lights-out packing in many of the Fonterra plants.

I believe that one of the factors for the success of processing in the NZ dairy industry has been the willingness to employ technical people such as chemical engineers – Fonterra employs probably 100s throughout the organisation and has a number in senior roles. This is another lesson to be learned by the rest of the primary industries.

Management and Governance

I spent 15 years as a research engineer involved in hands on chemical engineering and biotechnology. And, while I did not cease to be involved in chemical engineering, I then became a manager and moved through various roles including chief executive.

Since retiring from the dairy industry I have become involved in governance and advisory roles covering the whole of the primary industry – dairy, wool, meat, horticulture, seafood, arable and wood.

My work has given be a wide perspective of the primary industry. I am constantly amazed at how much exciting science and technology is around. And the potential for significant growth.

NZ needs this growth if it is to achieve the economic potential of which we are capable and desire. The primary industry is an engine room of the New Zealand economy. More than 80% of the products of the primary industry are exported, earning $30 billion per year, accounting for more than 55% of merchandisable exports and 20% of GDP. Twenty percent of the workforce is employed in agri-business. If we really want to achieve economic parity with Australia then we need to grow the value of our food and beverage exports at least three fold to $90 billion by 2025. This is an exciting challenge for the primary industry particularly to do this in a sustainable way given the limitations of land, water, nutrients and the increasing cost of energy. But it is possible.

In the 20 years to 2010 Denmark increased the value of its agricultural exports by 100% and their high and medium value manufacturing by nearly 400 %. We must do something similar.

I believe that the Government has taken some effective steps in the last couple of years to give this process a boost. The Primary Growth Partnership is investing $70 m per year in supporting commercial primary industry organisations grow their exports in a transformational and sustainable way. The NZ Food Innovation Network is providing open pilot plant facilities that will assist even the smallest of food companies develop their products economically. The Ministry of Science and Technology is now operating as a single entity. The CRI Task Force recommended some much needed reforms.

Commercial companies must now pick up the opportunities provided by these initiatives and get on with the task of achieving NZ’s economic potential.

But other areas need some attention. These include education, particularly to increase the number of students studying science and technology at school. And we must get a much higher percentage of our high quality university students studying science and technology subjects and being incentivised to stay in NZ or to return after a short time overseas.

There is also a huge innovation potential in our universities, but for this to be fully unleashed the Performance Based Research Fund must acknowledge that the work, reports, patents, etc which help to grow the economy by commercial exploitation are as valid as research papers published in peer reviewed journals.

When my friend Ken Kirkpatrick died last year, among his books I found, “The Philosophy and Logic of Chemical Engineering” by Howard Rase. A mutual friend, Ron Aird tells me that Ken probably purchased the book when he worked for the Dairy Board in Chicago. A concept which stands out for me from that book is that a distinguishing quality of an engineer is a sense of urgency.

It is that urgency which chemical engineers and other scientists and technologists will have to bring to the task of growing NZ’s economy faster.

Conclusion

I said earlier I was a chemical engineer by chance. I am not sure whether I think the way I do because I am chemical engineer or I am a chemical engineer because of the way I think. But I am convinced that what I have been able to do in my career is because I am a chemical engineer. There is no doubt in my mind that engineers think in a different way from lawyers and accountants and even scientists. And I know that organisations are the better for having a mixture of thinking styles in management and governance – this is a plea for all chemical engineers and other technologists to aspire to such roles. Take the opportunities that come your way to take up roles in management and particularly in governance.

Sandys Wunsch was a founding member of the Institution of Chemical Engineers, a leading figure in the lactose industry in NZ and, when he recognised the need for chemical engineers, he trained them himself. He would have been proud, perhaps surprised, at what has happened to the dairy industry since he retired in 1950. Miles Kennedy will also be proud of the efforts in the primary industry by the chemical engineering graduates he helped train.