INNOVATION AND SUSTAINABILITY
LESSONS FROM THE LIFE OF THOMAS MIDGLEY, JR.

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ABSTRACT

The array of topics addressed by the twin conferences, Sustainability and the Cold Chain, illustrates the broad range of issues that need to be understood by participants in the Refrigeration and Air Conditioning industry. It also emphasises the need for innovation and co-operation across businesses, market segments and continents. However some other important principles are less evident although equally important.

A key question which highlights these principles is "What makes an innovator?" The life and work of the American engineer Thomas Midgley Jr provides some insight. Midgley, the inventor of leaded petrol and CFCs, is much maligned: it has been said that he had more impact on the earth's atmosphere than any other single organism in the history of life on earth (McNeill, 2001). However in the context of the prevailing knowledge during his working life he was ignorant of the climate consequences of his work and was seeking to improve quality of life in exactly the same way as we all are. What can we learn from his example, if we look beyond the current supercilious view of his life's work?

1. INTRODUCTION

Figure 1 – Thomas Midgley Jr

Midgley was born in Beaver Falls, PA, in May 1889 and was educated in Columbus, OH and Stamford, CT before taking a BS degree in Mechanical Engineering at Cornell University in Icatha, NY. He had a healthy curiosity about a wide range of subjects, including aviation and motor cars, and enjoyed hands-on experiments, although not always in the core curriculum. When he graduated in 1911 he joined the National Cash Register Co in Dayton, OH, working for William A Chryst and Charles F Kettering in the Research Department, but after a year joined his father, an engineer with an automotive tyre company, working on the development of improved tread and cord patterns. In 1916, when the tyre company failed, he rejoined

Chryst and Kettering who had set up a research organisation, The Dayton Engineering Laboratory Company (Delco).

Over the next fifteen years Midgley was responsible for four major advances in the fields of engineering and chemistry. To improve the power output of aircraft engines during the war he developed the chemical tetraethyl lead as an anti-knock additive for fuel, which led to the creation of a process for extracting bromine from seawater. The bromine was added to the additive to prevent the build up of lead oxide on the engine valves. This in turn gave him experience of working with Group VII elements, the halides, and introduced him to the Dow Corporation and the EI DuPont de Nemours company who were partners in the bromine extraction and ethyl manufacturing businesses. This contact led him, with Kettering, to form a new company, Kinetic Chemicals Inc., to develop a safe refrigerant, R-12, on behalf of DuPont. His studies of halides had led him to conclude that any successful refrigerant would contain fluorine. His early years in the tyre business with his father coupled with his links to the automotive industry and his work combining hydrocarbons and halides also produced fruit in a new synthetic rubber and improvements to the vulcanising process.

2. PERSONAL TRAITS

Midgley seems to have combined an insatiable curiosity about how and why things happen with a deep-seated dissatisfaction with the current state of affairs and an unshakeable belief that he could make them better. He was also not deterred by setbacks, nor by finding that his initial ideas were ill-founded or insufficient. The route to the ethyl additive started with a belief that adding colouring to the fuel would help to absorb heat and vaporise it more completely. Iodine was used as the dye and had a remarkably beneficial effect, however when it was replaced with red aniline, the effect disappeared. Colourless ethyl iodide was added, and showed the same improvement: it was the iodine, not the colour that was significant. The inspiration for the colouring theory was said by Kettering to be the backs of the trailing arbutus leaves. Iodine was a lucky break – it was the only colorant available at the chemical store when the test was being run on a Saturday afternoon.

Another stroke of luck came in the early toxicology testing of Freon-12. Of the first five batches made for testing, four were poisonous and suggested that fluorine would be problematic. However the first batch tested had passed the toxicity test, so Midgley persevered and subsequently proved that the other four batches had all been contaminated.

As well as drawing inspiration from his observations of the natural world, Midgley was a firm believer in capturing experience from others. He was very personable and always interested in the opinions of others, from all walks of life. He had many interests outside of his laboratory, including history, zoology, writing poetry and recording music. When he took up golf he studied the theory intensely, reading books and discussing technique with professionals, so that his handicap was soon less than five. However the poor condition of the greens on his local course led him to experiment with different grasses on his estate near Columbus, and soon he was providing advice to green keepers from all over the county.

Kettering observed in his Biographical Memoir (1947) that *"Midgley demonstrated unusual talents in all three of the important phases of industrial research: first, in original investigation or invention; second, in development or in conversion to the stage of practical usefulness; and, third, in selling the new thing to the public – or in some instances to management first."*

3. WHAT MAKES AN INNOVATOR

So what makes an innovator and what lessons can we learn from Midgley's example?

- Be dissatisfied with the current state of affairs
- Draw on a broad range of observation and experience
- Engage with people who use the current technology in their everyday routine
- Be flexible and willing to modify the approach to a problem

Midgley himself observed in his Presidential Address to the American Chemical Society, titled "Accent on Youth" (1944) that 90% of the outstanding inventions lodged at the United States Patent Office were made by people under 45, leading to the comment that *"It would seem foolish to increase the time required for formal education beyond what it now is, since such increases would definitely encroach upon the most valuable years for actively prosecuting research and development."*

We can boil his message down into four key goals, which should be noted by all middle-aged executives:

- Pass responsibility to the young people in your organisation
- Help them to network with people outside their normal circle of contacts
- Let them exercise their curiosity
- Give them credit for what they achieve

As Midgley wrote, *"Napoleon proved himself the greatest military genius of our modern world at 27….(however) being 27 and in uniform does not generate the genius of Napoleon."* These eight points do not guarantee success in the development of new products and ideas, but putting them into practice is likely to increase the probability of successful innovation.

4. INNOVATION vs SUSTAINABILITY

For a refrigeration system to be considered sustainable it is necessary to address a broad range of criteria.

- is the cooling necessary, or might it be avoided completely?
- is the refrigeration system as energy efficient as possible?
- does the system consume resources to keep it running, or does it function without intervention?
- can the system achieve the original level of efficiency throughout its life?
- will the system require replacement in a few years or is it built to last?

In each of these points there is a balance to be struck between innovation and sustainability. To waste resource continually by "re-inventing the wheel" is not a good example of sustainable behaviour: the engineering resource committed to achieving the innovation could perhaps be better employed delivering advances in other areas.

4.1 Is the cooling necessary?

The most innovative and sustainable cold chain link would be one which required no refrigeration, yet achieved the key objectives of delivering fresh produce from harvest to consumer without waste. In this sense refrigeration does not "add value" to the produce, rather it minimises the reduction in value caused by wastage. It is difficult to envisage a cold chain without refrigeration, but it would bring significant benefits. Even if cooling cannot be eliminated the advantages of minimising the requirement could be significant. For example developing fruit, vegetables and dairy products that permitted a relaxation in storage temperatures would deliver a twin benefit. The average storage temperature could be raised, and the width of the control band could be increased, enabling more efficient modes of operation to be adopted.

4.2 Is the system as efficient as possible?

Assuming that cooling is required there is again a possible balance of innovation and sustainability to be struck. We should all be dissatisfied with the current levels of efficiency in cold chain equipment and yet based on the evidence of the system types that are installed year after year it is impossible to avoid the conclusion that current practice is deemed to be "good enough". Supermarket systems that use superheat-controlled expansion valves and cross-flow heat exchangers are a good example. It would be possible raise the suction pressure of a supermarket pack by about 5K if the system were re-designed to eliminate superheat, or if the airflow through the heat exchanger were reconfigured to provide superheat in a counterflow arrangement, but this is not done.

4.3 **Does the system function without intervention?**

Again the status quo seems to be acceptable. We have supermarket systems known to leak anything between 10% and 40% of their total refrigerant charge each year and the link between refrigerant loss and environmental damage is well-established but simple measures to address this refrigerant loss were not taken for many years. We are now seeing an interest in minimising the HFC refrigerant charge in supermarkets through the adoption of cascade and transcritical carbon dioxide systems, but simple steps to reduce refrigerant leakage are still not taken. These include avoiding copper pipe, eliminating brazed connections and not using fragile components such as vibration eliminators or small diameter gauge lines. Even with carbon dioxide as the refrigerant there are environmental implications of refrigerant loss. Someone has to drive to site to replace the lost gas. Someone else has to purify and liquefy the gas to be charged into the system. Someone has to pay the increased fuel bill which results from running a system inefficiently through lack of refrigerant.

4.4 **Whole-life efficiency**

It is no longer sufficient just to have designed and installed an efficient system. If decisions taken on the basis of life cycle costing are to have any worth then it is essential that a reasonable estimate of the actual efficiency of the system throughout its life is used. This raises the importance of keeping the plant at original efficiency throughout its life. There are many ways in which efficiency can be impaired over time: small leaks in control valves can bleed high pressure gas to the suction side creating a false load, heat exchangers on the high and low sides can become fouled and of course compressors can wear and lose efficiency. These deficiencies can be minimised at the design stage by ensuring that equipment can be cleaned and serviced, and by minimising possible leakage paths.

4.5 **Life cycle expectations**

In addition to efficiency it is also necessary to consider the general resilience of the system. Consideration of sustainability would suggest that installations should use as little raw material as possible, but this could lead to inefficient operation or premature failure. Aluminium is a great material for heat transfer, but it requires nearly five times more energy per kg to process than galvanised steel (MacKay, 2009). It is only 40% of the density and 90% of the yield strength of steel or stainless steel, so the embedded energy in a system constructed from all aluminium heat exchangers and pipes would be about twice that of a traditional steel system. However, if that energy can be offset over the life of the system through increased CoP then the investment is worthwhile. To extend the life of systems more use could be made of aluminium alloys and stainless steel, but they must be deployed in suitable applications where their advantages are useful, but their disadvantages are minimised.

It is clear from these examples that sustainability and innovation can be nurtured through appropriate guidance and incentives. In the White Paper "Innovation Nation", presented to the UK Government by the Department for Innovation, Universities and Skills (2008), a very broad definition of innovation was adopted. *"…innovation draws on a wide variety of sources and is driven as much by demand as by supply. The insights generated by basic science are critical to long-term innovation performance but the path they follow from the laboratory to the marketplace is long, complex and uncertain. Other sources of innovation include the creative application of tried-and-tested technologies and the role of design in developing innovative products and services. Innovation is also not restricted to the private sector – increasingly the public sector is called upon (often in partnership with the private and third sectors) to innovate in the design and delivery of public services."* The White Paper emphasises the role that government has to play in developing a national culture of innovation, through procurement policy, incentives and regulation, recognising that regulation can promote or hinder innovation.

Government also has a role to play, particularly through public works, in promoting sustainability. In this respect the UK Government has been willing to promote the use of natural refrigerants including ammonia and propylene through the specification of natural refrigerants for chillers on government buildings. In London alone there are chillers using ammonia on offices, conference centres, laboratories and hospitals. However the recent reduction in the cost of carbon credits (MacKay, 2009) shows that market mechanisms are not sufficient to ensure effective action. Figure 2, from "Sustainable Energy – Without the Hot Air"

(2009) shows the price in euros of one tonne of CO_2 emissions in the first European trading scheme, from March 2005 to December 2007. MacKay writes *"I still wonder whether it would be wisest to close the stable door directly, rather than fiddling with an international market that is merely intended to encourage stable door-closing."*

Figure 2 – Price in euros of 1 tonne of CO_2

5. WHERE DO WE GO FROM HERE?

MacKay demonstrates convincingly that significant radical action is required to make any meaningful change to our emissions performance and improve the sustainability of our actions. He offers three motivations for modifying our behaviour, all in the context of general energy policy:

- Fossil fuels are a finite resource, so we should plan for their eventual disappearance
- Fossil fuels are becoming increasingly difficult to extract, so continuity of supply is doubtful
- Use of fossil fuels is very probably causing climate change

Similar motivations can be derived for the cold chain:

- Refrigeration is expensive and does not add value to produce, it minimises loss of value
- The life cycle climate performance of fluorocarbon refrigerants cannot be sustained
- Use of fossil fuels is very probably causing climate change – improving cold chain efficiency is paramount

Kuijpers (2009) observed that the transition from CFCs to HCFCs was achieved over a 25 year period, with relative ease, but to transition from "third generation" halocarbons (HFCs) to low-GWP alternatives presents significant additional challenges, and must be completed within the next decade. More difficult questions are being asked, and less time is being given to answer them. Much of this acceleration is driven by the twin international agreements, Montreal and Kyoto, with a growing realisation that a holistic approach to climate inpacts is required if policy is to be effective.

At national level, in the United Kingdom, the Innovation Nation White Paper was an encouraging start. It is disappointing however to note that the "first annual" review of progress was published in December 2008, but at the time of writing (February 2010) there is no sign of the second annual review. Meanwhile the Department of Innovation, Universities and Skills was subsumed into the newly formed Department for Business, Innovation and Skills in July 2009. As Peter Mandelson, Secretary of State at BIS, said "Innovation … is our middle name" (Mandelson, 2009). He enumerated four steps to the creation of an innovation infrastructure:

- "…we need to do more … to translate our record investments in our world leading science base into commercial innovations"
- "…to recognize and get to grips with the unique challenge of financing innovation"
- "…to embed innovation into our higher education and skills systems"

- "…to drive innovation through public procurement – above all by widening the access of innovative small firms to the procurement process"

This is very encouraging, but it needs to be put into practice and set against comparable activities elsewhere, to get a true picture of priorities. The initial Innovation Investment Fund created by BIS is £150,000,000. This seems like a lot of money to any individual researcher, but as MacKay points out in chapter 28 of "Sustainable Energy – Without the Hot Air" figures 28.5 and 28.6 there are many things that "run into billions". Examples he gives include:

- the cost of refurbishing MOD offices £1.5b
- the cost of widening the M1 motorway £1.9b
- the cost of Heathrow T5 £4.3b
- the cost of refurbishing an army barracks £8.3b
- the current estimate for the London Olympics £9.0b

On this scale the Innovation Investment Fund is a slender-looking £0.15b. The success of Innovation Nation in fostering innovative behaviour in individuals and small businesses is equally important, but less tangible. However it is this activity, more than just throwing money at the situation, that will deliver success.

Judged through the compressing effect of the passage of time Thomas Midgley's two greatest successes turned out to be two of our greatest environmental headaches. He seems to have had no concerns about sustainability, but on closer inspection it is evident that he, like us, was interested in delivering long-term benefits for the good of mankind. In "Accent on Youth" (1944), published just one month before he died, he wrote:

> "*Youth is original and creative, while age is simply experience. Both are essential elements on any team that is to make for lasting progress*."

The industries which serve and support the cold chain should be creating multi-discipline, multi-age teams blending creativity and experience and battling vigorously for a share of investment in renewables and sustainability, in preparation for the next ten years. As we move towards the development of a new family of halogenated fluorocarbons we are duty bound to take a more thorough approach to short and long term environmental effects – however in doing so, to paraphrase Isaac Newton, we can see further because we are standing on the shoulders of giants like Thomas Midgley and Charles Kettering.

6. REFERENCES

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