80 years
of the Institution of Agricultural Engineers

Horizons

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IAgrE
A **Landwards** publication

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EDITORIAL:

WINDOW ON OUR WORLD

Perception is everything. So, what does the term Agricultural Engineer mean to the public at large? Probably no more than 'something to do with tractors'.

Much of our work, many of our achievements are carried out under the radar. Never hitting the public consciousness to any large degree. We are support players in delivering that most basic requirements of man – the provision of food and the sustainability of our planet.

Our role is diverse and varied, but in addition to informing those in authority, we also need to constantly remind ourselves of the important place we occupy in the land-based sector in particular, and engineering in general.

The 80th Anniversary of IAgrE is important, but it is a mere stepping stone to exciting times ahead. I would like to thank the collective IAgrE 'family' for stepping forward and contributing such a varied and well-crafted collection of essays and contributions for this special commemorative publication.

As well as reminding ourselves of the wide-ranging role that IAgrE plays, it will hopefully provide a Window on our World to those outside.

Chris Biddle
Editor

CONTENTS:

AGRICULTURAL ENGINEERING: AN EVER-EXPANDING REMIT

As current President of the Institution of Agricultural Engineers, I am delighted to introduce this special commemorative publication to mark the 80th Anniversary of the Institution. It is an honour to follow in the footsteps of so many influential past IAgrE Presidents (realising these are a very hard act to follow!).

From the roll call of my predecessors alone, it is obvious that agricultural engineering has always been a diverse, dynamic and developing discipline . . . and long may this continue.

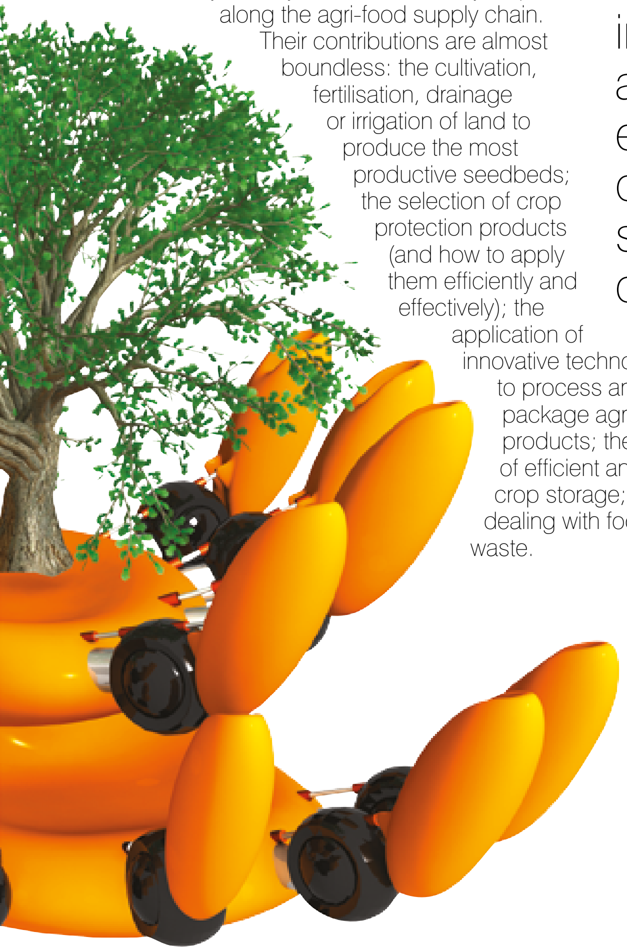
The contributions in this publication reflect the role of agricultural engineering over the past 80 years. I would argue that "ag eng" (as it is affectionately known) has been either directly or indirectly responsible for improving the quantity and quality of a huge range of goods and services that we get from our precious land resources.

They contribute at every step along the agri-food supply chain.

Ultimately, many of these goods and services have been linked to human health and well-being, including the ability to produce safe, nutritious food, over 95% of which comes from land. By applying engineering, technology and science to agriculture, agricultural engineering is at the heart of food security.

Making food available, affordable and accessible through developments in agricultural engineering really matters in our daily lives. I'm sure many people will remember the UK government Security Service's maxim that society is only "four meals away from anarchy".

Agricultural engineers are fundamental to this story as they contribute at every step along the agri-food supply chain. Their contributions are almost boundless: the cultivation, fertilisation, drainage or irrigation of land to produce the most productive seedbeds; the selection of crop protection products (and how to apply them efficiently and effectively); the application of innovative technologies to process and package agricultural products; the design of efficient and safe crop storage; and dealing with food waste.



The traditional image of the agricultural engineer has changed significantly over time.

However, agricultural engineering is of course not just about food production: it encompasses other landbased industries too, including forestry, amenity, landscaping, rural renewable energy, environment and bioresource production.

The ever-expanding remit of agricultural engineering is reflected by the articles in this publication, from evolution of tractor technologies to sustainable timber production. The wide-ranging scope of agricultural engineering in the 21st century demonstrates how the traditional image of the agricultural engineer has changed significantly over time.

As we celebrate the contributions of the IAgrE over the past 80 years, we should also recognise how agricultural engineering can make important contributions in the future, especially in the light of the new Agriculture Bill, the replacement of the Common Agricultural Policy and the 25 Year Environment Plan. Agricultural engineers are driving exciting developments in precision agriculture, digital technologies, machinery design and robotics to improve field and farm practices.

Many of these advances will address some of the world's greatest challenges - food security, coping with climate change, protecting our environment and sustaining rural livelihoods.

These issues need scientific and technological solutions that will rely on well trained and well qualified agricultural engineers at all levels, supported by their professional Institution, the IAgrE.

Professor Jane Rickson
CEnv FIAgrE

President 2018-2020
Institution of Agricultural Engineers

FOREWARD

Alasdair Coates

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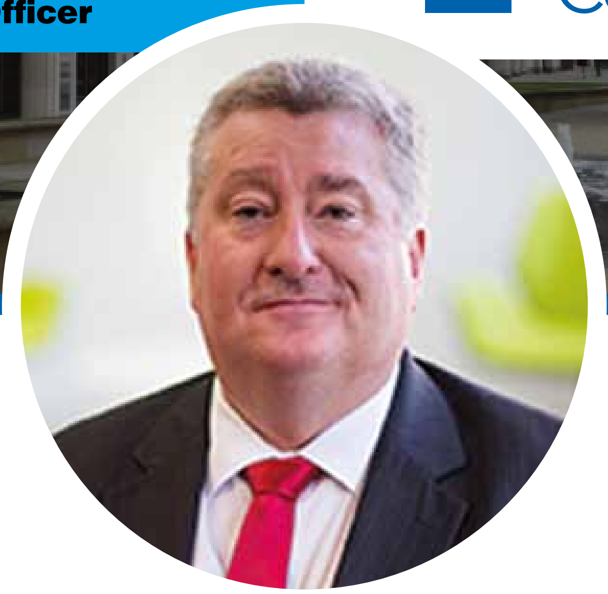
Chief Executive Officer

Engineering Council



The 80th anniversary of the Institution of Agricultural Engineers (IAgrE) is a milestone in the history of an organisation that works to put knowledge and professionalism at the heart of its sector.

IAgrE demonstrates its commitment to high standards in landbased engineering by offering professional registration through the Engineering Council and the Society for the Environment, as well as registration with the Landbased Technician and Parlour Safe Accreditation Schemes.

As the UK regulatory body for the engineering profession, the Engineering Council maintains internationally recognised standards of competence and commitment for the engineering profession and holds the register of over 230,000 engineers and technicians who have been assessed against those standards. We license competent institutions to champion those standards and assess candidates for registration, ensuring society can have confidence in their knowledge, experience and commitment.

We are pleased to recognise IAgrE as one of those competent institutions and to see that recognition of the value of having an independent verification of competence applies to IAgrE's Secretariat as well as its membership, since Chief Executive & Secretary Alastair Taylor is himself a Incorporated Engineer.

IAgrE has been able to assess its members for professional registration through the Engineering Council for more than 30 years, having become a Licenced Member in 1985. Technology has changed enormously since IAgrE was originally established, but its fundamental principles of promoting good practice and making sustainable use of energy and materials remain.

Agriculture and the environment are the basis for all other activities, producing food for the population and managing the environment in which we all live.

The skills required to achieve this effectively and sustainably are therefore enormously important not only to the practice of engineering, but to humanity in general. In this Year of Engineering 2018, IAgrE's 80th anniversary is a reminder of how essential engineers and technicians are to the world and the difference that skilled, competent individuals can make.

IAgrE and the Engineering Council share a commitment to the public benefit and to supporting industry in its broadest sense. In collaboration with the professional engineering community, we will continue to ensure that professionally registered engineers and technicians demonstrate their competence and commitment to the profession and are able to work in an ethical, sustainable and safe manner.

We congratulate IAgrE on its 80th anniversary and wish the institution many more years of promoting the profession of landbased engineering to the benefit of the public.

FROM THE CHIEF EXECUTIVE

TOGETHER, WE CAN

When the IAgrE founding fathers started out in 1938, they established some very clear aims and objectives for the Institution. These undergo periodic review but what is clear is that these are as valid in the early twenty first century as they ever have been – and are worth repeating. IAgrE will:

- Promote the consideration and discussion of all subjects affecting the profession of Agricultural Engineering and facilitate the exchange of information and ideas.
- Disseminate information on all matters relating to Agricultural Engineering and produce relevant publications.
- Encourage and support invention, innovation and research in matters connected with Agricultural Engineering.
- Co-operate with educational institutions for the furtherance of education in Agricultural Engineering.
- Give legislative, public and other bodies facilities for ascertaining the views of those engaged in Agricultural Engineering.

Many people seek to be associated with these principles by becoming a member of IAgrE, and part of a community of the people seeking to address the Institution's objectives. Others go on to seek professional registration, either as an engineer or environmentalist and view that as an important way of demonstrating their commitment to professionalism.

In engineering circles, IAgrE is referred to as a Professional Engineering Institution (PEI) and is one of over thirty similar organisations who work in the public interest. Different people have different motives for their IAgrE membership, and some get more involved than others, but the old adage remains true that 'you get out what you put in'. So over the years, there have been many people who have enjoyed significant career development and benefits from their association with IAgrE.

As we look to the future, IAgrE is focused on those important key messages which resonate with today's workforce.

Our core message is that IAgrE exists to support your professional life. It does this by enhancing your professional networks, professional standing and professional knowledge. The key point here is the word "professionalism" and all IAgrE members are making that important commitment, regardless of whether they go on to become a registered professional with the Engineering Council or the Society for the Environment.

In a world where information is available at the click of a mouse and people move between job roles; in a world where science, engineering and technology is evolving at what feels like a logarithmic pace; the need to be part of a trusted community has never been more important.

Society has never been better connected – and yet at the same time we have never been lonelier. IAgrE can be that single point of continuity in a chaotic and fast moving world. For many people, IAgrE has been, and continues to be that one reliable constant – and we all need that.

If this publication does one thing, it showcases past and future developments in the exciting world of Agricultural Engineering. We are at the frontier of such exciting, innovative times. We have a need for many more multi-disciplinary engineers and technologists to meet the challenge of feeding the growing world population - at the same time protecting the planet and its precious resources.

Our mission for the next eighty years is to continue as the natural home for those people engaged in the ever more diverse agricultural engineering and technology sector. By pursuing that aspiration we can remain as the key point of focus for those original aims and objectives and remain faithful to the ambitions of our forefathers.

That is why IAgrE exists, and will continue to exist. Our motto must surely be 'Together We Can'.

Alastair Taylor
IEng CEnv MIAgrE
Chief Executive and Secretary
Institution of Agricultural Engineers

FOREWARD

Emma Wilcox

CMgr FCMI

Chief Executive Officer

SocEnv
Society for the Environment

80 Years Young: Happy Anniversary IAgrE

The Institution of Agricultural Engineers (IAgrE) formed part of the initial group of ten professional bodies who became the first Constituent Bodies of the Society for the Environment in 2004 and were instrumental in the Society's successful application for a Royal Charter. The Society is proud of the continued relationship with IAgrE, who are now one of twenty-five Constituent Bodies.

IAgrE have been a long standing, trusted member of the Society, which continues to this day. The input of volunteers, including the Society's current Chief Licence Reviewer, Ralph Alcock CEnv, and IAgrE CEO, Alastair Taylor CEnv, who is a current member of the Society's Registration Authority (RA), together with the previous IAgrE RA representative Steve Parkin CEnv, have been critical to the development of the Society as a whole. This stems from a legacy of diligent IAgrE volunteers from the very beginning of our journey, such as Peter Redman HonFSE CEnv and Chris Whetnall HonFSE CEnv who were the IAgrE representatives at the inaugural Council meetings.

IAgrE have also been licenced to award the Chartered Environmentalist (CEnv) registration since 2004, and have since registered a wide range of environmental experts across numerous specialist disciplines. IAgrE members were amongst the first to gain CEnv registration, who now join over 7,400 registered as CEnvs from across the Society's Licensed Professional Bodies.

To provide an insight into the development that IAgrE have been fundamental to, the ten founding professional bodies represented c30,000 members. In comparison, the current Constituent Bodies represent over 500,000 members!

We are however very aware that it is not simply a numbers game. The Society's robust, ever-relevant registration processes and requirements are key to ensuring that the registrations available continue to be appropriate for environmental professionals. This would not be possible without the work carried out by our valued Constituent Bodies and volunteer commitment.

There are simply too many contributions from over the years to detail within a few words, but IAgrE has our full respect, trust and admiration. As the Society enters its fifteenth year, it will continue to learn from the successes and challenges seen by its more experienced partners.

From the Society for the Environment as a whole, we congratulate you on your achievements so far, wish you well for the future and look forward to many more years of successful partnership.

ABOVE *Left to right: Mark Kibblewhite CEnv, Peter Redman HonFSE CEnv, Chris Whetnall HonFSE CEnv and Alastair Taylor CEnv at the Society's 2015 Christmas Reception*

FOREWARD

Dr David Llewellyn

Vice-Chancellor

Harper Adams University

The world of agriculture is rapidly changing, and it is clear that engineering and technology will play an increasingly critical role in delivering for the industry increased productivity, improved profitability and greater traceability. Yet more benefits could be derived for environmental land management, one of the major themes of the Government's new Agriculture Bill. However, we need to do more to translate these aspirations into action, so that farmers and growers have greater awareness of the potential for new technologies to improve their business performance, and the support available to build appropriate innovations into their future plans.

By working together, the Institution and educational providers can assist this period of change. Harper Adams University has been strongly connected with the activities of the Institution over many years, and regular engagement on engineering policy, as well as practice, has enabled us to better promote the cause of agricultural engineering with other organisations and within Government.

One example, at the time of the Foresight Panel Report on the Future of Farming and Food, and the emergence of the debate about the challenge of global food security, was our joint intervention with the Government Office for Science to ensure that agricultural engineering was seen as part of the solution. Working with industry and other educational and research organisations, the Institution produced an influential report on the key discipline of agricultural engineering that later featured in the UK Strategy for Agricultural Technologies. This, in turn, supported the inclusion of agri-tech in the Clean Growth strand of the current Government's Industrial Strategy.

In education and knowledge exchange there have also been significant examples where we have worked on common objectives. A major careers conference organised by the Institution and the Douglas Bomford Trust, held at the University a few years ago, attracted over 300 budding engineers and helped inform them about the role they could play in feeding the world. More recently, the Institution was engaged in the Annual Congress of the Engineering Professor's Council, hosted by the University, where we took the opportunity to raise the profile of the profession with engineering education leaders and industry representatives from all over the UK.

Through these activities, and many others like them, we have sought to produce the next generation of agricultural engineers and agriculturalists who can make innovative contributions to the leadership of the industry and to the effective management of businesses, food production and the environment.

Our ground-breaking research, such as the Hands Free Hectare project, has also been recognised for its potential to change agricultural practice and its contribution to promoting agricultural engineering worldwide. We were delighted that The IAgrE Team Achievement Award, a special award in celebration of the 80th Anniversary of the Institution, went to the young team of Hands Free Hectare engineers. This category recognised 'what can be achieved through collaboration'. I hope that it is evident, from the examples provided here, that the Institution and the University have achieved a lot through working together, and long may that continue. In the meantime, we wish the Institution many congratulations on the occasion of its 80th Anniversary.

THE TRACTOR

EARLY DAYS: THE UK'S ROLE

Post-war, the National Institute of Agriculture Engineering played a pivotal role in the design, efficiency and safety of farm tractors. Former IAgrE President, **John Matthews**, Director of NIAE from 1984 to 1990 reflects on research that has shaped the tractor of today

The main reason I wish to write this is a strong feeling that few will know of the UK's role during this period – a time of great change in tractors, as in all technology. The industry and the R&D infrastructure deserves recognition and I was privileged to have an inside view of the efforts and progress made.

World War II and just after, during a period of rationing, found British agriculture struggling to feed the nation. Pastures were ploughed up, cereals and root crops grown as never before and livestock numbers increased. Most farms in 1939 were 'powered' by horses and manned by large numbers of workers compared to today.

I was a nine-year old living in a village in North Buckinghamshire. There were only two tractors in the village along with perhaps 12-16 pairs of 'Shire' horses. Both tractors were orange Fordsons with pneumatic tyres and, fortunately one was on the farm of the village butcher just along the road from my father's bakery.

I started to spend time on the farm and was soon allowed to drive the tractor – initially just between stooks of corn. Two Shires were used for mowing, turning and raking hay and some carting. The only larger tractors I saw (and I was never allowed to drive them) were US-built machines and either Olivers or Minneapolis Moline, but I did encounter my first 'grey Fergie' at school harvest camp in Staffordshire.

On leaving school in 1948, I spent some time on a farm before joining the RAF and then working in research for the General Electric Company. An advertisement for a physicist,

which I had by then become, to work at the National Institute of Agricultural Engineering was irresistible and I joined the Grain Department to work on moisture content measurement and control. The Institute was obviously a place to get excited again about tractors as all UK and some overseas models arrived for test or research projects.

Up to that time (1959) the Institute staff had concentrated on understanding and measuring tractor performance on tyres, tractor operation in tropical areas and on engine wear and the resistance to dust ingress.

David Manby had studied, with financial support from the tyre and rubber industries, the effects of tyre profile on tractive performance. He also quantified the effects of water ballast in tyres. A single-wheel tester was built and tread patterns assessed – all this work needing to encompass the wide range of soil conditions met in UK and overseas agriculture.

By 1960, tractor tests had become formalised and in some areas compulsory. The OEEC (later OECD) had an agreed international procedure with the results being considered 'official' in most European countries and with the Test compulsory for tractors imported into Greece. In the USA the Nebraska Test was similar and compulsory for tractors sold in that State. Doubt about through-life performance was such in the UK that power and condition checks were being made by NIAE on farm tractors scattered across the UK.

One area where tractors were performing badly was the tropics. The East Africa Testing Unit was established with assistance from the Foreign Office. It was equipped with a portable dynamometer and contributed a great deal to making fueling and timing adjustments to tractors to improve their performance at the higher temperature and altitudes encountered. Work was also done to establish the nature and effect of dusty environments.

Dust damage led to much work at Silsoe on air cleaner efficiency. Air cleaner designs were developed by manufacturers. The NIAE role was one of testing. To measure engine wear pioneering work was done with the use of radio-isotopes in special piston rings.

The tractor industry in the UK at the time I joined NIAE consisted of five main companies and three significant smaller ones. Massey Ferguson, Ford, International Harvester, David Brown and Leyland together constituted the largest national producer outside USSR. (We did not know their statistics.) County, Roadless and Muirhill manufactured or assembled more specialised machines – four-wheel driven – employing components or even main body units from the large manufacturers. Most models were within the range 25-75 horsepower, the upper limit creeping up to 100 hp over the next two decades.

The main manufacturers at that stage did not produce 4-wheel drive vehicles and this is where County (specialising in four equal-sized wheels) and Roadless (small front driven wheels) found a market. Muirhill spread to agriculture from the civil engineering industry. Readers will, of course, know other tractors of the time – Caterpillar tracklayers, Marshall 2-cylinder models, for example.

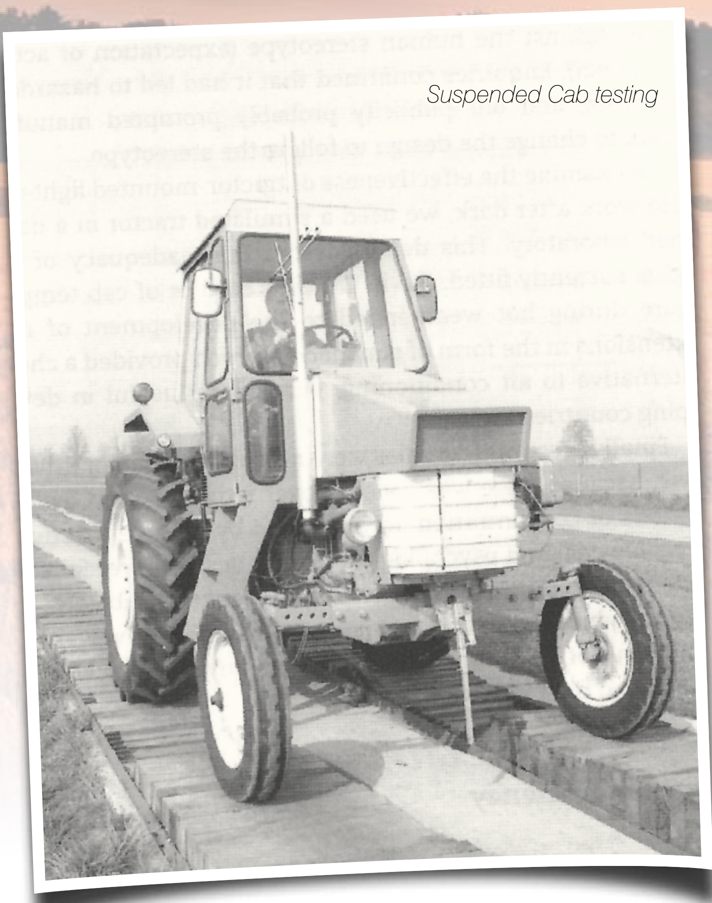
DRIVER COMFORT

After two years in the Grain Department I moved on to new duties which included research into driver comfort in relation to the ride vibration encountered over rough agricultural surfaces. Earlier research had demonstrated a clear link between tractor driving and both stomach complaints and spinal damage.

Our role was to analyse the vibration severity on a range of farm tasks and tractor types in the UK and to identify ways in which the vibration might be ameliorated. From field measurements and computer simulations, the benefits of sprung seats, suspension cabs, of sprung front axles and of complete suspensions were predicted. The importance of tyres was quantified and satisfyingly the work fed into the establishment of agreed international standards relating 'whole body' vibration to risks to health and to levels of comfort.

Suspension seats were seen to be able to improve ride and yet some on the market led to worse ride than solid seats. Over the next few years the Institute built and investigated sprung (suspended) cabs, sprung front axles and complete four wheel suspensions. These are, of course, now commercially available.

Alongside the engineering developments and because of the, by then, generally accepted health risk it was necessary to develop a method to repeatedly measure the ride vibration. This could only be done by agreeing



Suspended Cab testing

standardised rough surfaces over which tractors can be driven.

In parallel with the vibration problem, that of noise was also identified as a driver health problem. Measurements at the driver's ear position, both on tractors without cabs and on those fitted with the cabs of the period, showed noise levels likely to damage hearing. Audiological (hearing) tests carried out in collaboration between NIAE and Loughborough University confirmed that hearing had been damaged on a representative sample of tractor drivers and that this worsened with the time driving.

Despite the fact that noise levels were generally higher on tractors with cabs, we realised that cabs were likely to be the norm in the future due to the need for weather protection. NIAE research therefore concentrated on how to quieten cabs. Among the possible solutions studied were sound barriers between engine, transmission and driver, sound absorption in the cab, the sealing of inlets necessary for controls, anti-vibration mounts to avoid cab resonance and damping of the cab framework.

The result was the emergence of cabs from all manufacturers capable of reducing noise levels to below the damage level of 90 dBA. Initially 85 dBA was common, but later refinements have made even 75 dBA attainable.

SAFETY

Concern at the incidence of tractor overturn accidents probably began in Scandinavia, particularly Sweden in the late 1950s. It became compulsory for tractors to be fitted with roll bars or frameworks to prevent crushing of the driver, the concern and its solution soon spreading to other countries.

In the UK it was clear that more than 100 fatalities were being encountered annually from overturned tractors. Research was given priority to confirm the best way to ensure the effectiveness of safety frames and cabs, and also to assess devices for preventing the continuing rolling of tractors on hillside slopes.

Research in several countries – from Sweden to New Zealand – was co-ordinated through the OECD and the International Standards Organisation. For all but the largest tractor models the strength test was based on a swinging 2-ton weight, the height of swing and hence the energy imparted, being determined by the weight of the tractor. By the mid-1970s all tractors in the UK to be driven by an employee had to be fitted with an approved cab or safety frame (simple roll-bars could pass the test). At one stage we were doing 3-4 tests each week at NIAE, including failures and retests of course. The reward for the manufacturers, the Ministry and us was that fatalities were reduced to a handful.

Research continued with an instrumented tractor tumbled down an artificial ramp to build a mathematical model of the overturn and impacts. For larger tractors in particular, it helped in introducing static force tests using rams. Parallel research, on a much smaller scale, studied possible head impacts suffered by the driver in overturns. An anthropomorphic dummy (artificial man) was seated in a cab attached to a mechanism allowing it to overturn. Tests were carried out with 'hands', both attached to the steering wheel and free. The severity of head impacts on the cab walls was measured with instrumentation, showing that skull fracture was unlikely on plane rigid surfaces but a real danger on corners or exposed struts. These conclusions obviously affected cab interior design.

Less drastic, but significantly affecting driver comfort and efficiency, is the ease of access to the seat and the design of seat and layout of controls in relation to the seat. Each of these aspects were studied by the Institute using an adjustable tractor/cab rig in the laboratory and a range of subjects of varying stature and weight. The results certainly led to the easy-access, comfortable tractors we know today. In years following, we completed our studies of the ergonomics of tractors and cabs by studies of swiveling seats, offset seats, tractor lighting for night work and cab climate control in hot conditions.

TRACTOR EFFICIENCY

Although the ergonomics of the tractor is very important to ensure driver safety and skilled driving, most people recognise the tractor as a machine to pull implements or trailers, or to power them efficiently through the PTO

From the first, the NIAE has enjoyed a reputation as the world's leading body in the search for maximum tractor working efficiency. In the 1960s and 1970s new 'single wheel tester' and 'rolling resistance measuring' rigs were built and these allowed a detailed understanding of the effects of tyre size, construction, inflation pressure and wear to be developed and related to each of the wide range of soil types and conditions on which tractors work.

To further ensure that potential improvements were realised, comparison trials and demonstrations were made of two- and four-wheel drive tractors with identical engines and, in the case of the four-wheel drives, with smaller front wheels and with those of equal size to the rear wheels.

Rollover tests of safety frames on Chiltern Hills

These trials clearly demonstrated the sizeable advantage of the extra driven wheels and of the larger over the smaller.

Dual tyres were also assessed in relation to their draught capacity and their rolling resistance on soft soils. Single wider tyres were seen to have disadvantages over duals due to the build-up of soil in front of the tyre. The rig for measuring rolling resistance was also employed to measure the steering force which various tyre types could generate, important in heavy draught work.

Working speeds of tractors were increasing but in the late 1970s it was clear from calculating optimum field-working and transport speeds that we could make economic savings.

Our studies showed that economy improved at higher speeds than were then common, peaking at 6 – 8 mph for mould-board ploughing and 10 – 12 mph with a chisel plough. From other 'work study' simulations it also became clear that increased transport speeds, both on farm tracks and on public roads, could vastly improve the economics of harvesting and other transport tasks. This work also suggested 120 – 140 hp tractors were more economic that 70 – 90 hp models on larger UK farms.

MANUFACTURER INPUT

This search for higher speeds was partly responsible in 1976 for a multi-million pound contract led by the Institute and sponsored by the then eight UK tractor manufacturers, five component and implement manufacturers and the Department of Trade and Industry which studied several aspects of present and future tractor use.

Ride vibration at higher speeds and the influence and practicability of both front-axle and rear axle suspensions was one subject.

Another part of the project looked at the steering and braking safety of higher speed tractors, both on level surfaces and on slopes. This particularly focused on hitched trailers with heavy loads. The performance of three-point linked implements and tractor draught and depth control systems was analysed and novel systems were devised for higher speed working.

In the search for ever-improving reliability the manufacturers also sought better knowledge of the in-service loading and stresses on tractors and tractor components. Six hundred machines were therefore followed over a 12-month period to show average and extreme working patterns. These were all newer vehicles to show the work expected over the first five or so years of use, they were spread on farms throughout the UK. Drivers were enlisted to record the use data and several other factors, but on 10 percent of the vehicles, fuel flow meters were fitted to automatically indicate the power levels employed. Instrumentation perfected by the Scottish Institute allowed the usage patterns to be translated into torque and stress data for principal components.

NEW CONCEPTS

The general shape of tractors has changed little since the days of the 'Ivel' and certainly not since the Fordson and 'grey Fergie'. The size, power and speeds have, of course, advanced considerably.

Really fundamental design changes have been attempted in two main directions. To increase speeds, vehicles hybrid between the tractors and the 'Jeep/Land Rover' vehicle have been built and widely trialed. The 'Trantor' is a case in point, but commercially only the German 'Unimog' appears to have made any significant market advance. Higher speed, often suspension-fitted vehicles, such as the JCB Fastrack, have probably achieved much more.

Looking backward to the 1960s, another rather revolutionary concept pioneered by NIAE was to replace the gear transmission by a hydrostatic (hydraulic) system, the benefit being to clear space within the tractor chassis area to allow implements to be better located within the tractor volume. Although the project was technically successful, the concept was not taken up commercially for tractors although these transmissions were much used on self-propelled machinery where the transmission geometry is much more complex.

Almost all of the reported research into driverless tractors and field machines at the time I retired (1990) was carried out in the UK.

In the 1950s the Electrical Research Association developed at Shinfield, Berks a 'dead reckoning' control system. With this system the distance travelled and direction followed (by compass) were measured allowing a 'prediction' of the tractor's position. Wheel slip and system errors severely limited the accuracy of the system which therefore did not reach any stage of commercial interest.

Also at Shinfield, David Brooke pioneered a system based on buried cable carrying an electric current, which could be detected and followed by the vehicle. He even promoted an adaption of the system in which the cables were laid far apart so that the graduating electric field between them could be used as a position reference. Manufacture interest stretched to the loan of vehicles, but again there was little market interest with only 2-3 systems installed on golf courses, etc.

The NIAE approach, from the early 1960s, was to develop a system based on following work done which was combined with a 'headland' turning programme. An ultrasonic detector was designed to locate the furrow edge in ploughing. For headland detection and turning, an optical system with fixed beams was erected in the field of work. Yet again there was relatively little market interest and the project was terminated in the late 1970s – but it must be remembered that each of these activities predated GPS and even lasers!

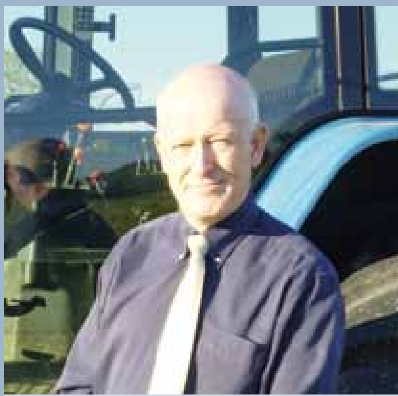
CONCLUSION

For 80 years tractors have become larger, faster and more complex with increased gears, power take-off points, front and rear implement attachments and a much greater degree of comfort and of safety. 'Conventional' tractors seem likely to continue to out-number high speed (Land Rover type) machines, gantries and specialised transport vehicles. Automation is likely to concentrate on maximising the efficiency and accuracy of the tractor-implement combination rather than replacing the driver.

Images from Agricultural Engineering: The Wrest Park Story 1924-2006 published by Elesevier Ltd

Tyre performance testing

THE TRACTOR - EVOLUTION FROM 1990



The tractor remains the prime-mover in modern agriculture. **Dr Andy Scarlett** MIAgrE, former leader of Silsoe Research Institute's Field Machinery Centre and Director of Scarlett Research Ltd reviews developments from 1990 to the present day and considers where the future may lead.

What factors have actually influenced tractor development over the last 30 years? Yes, most certainly the availability of suitable technologies in reliable forms, but is this the key driver? In truth user needs (whether real or perceived) and regulatory requirements have probably had the greatest impact upon the nature and rate of tractor evolution.

Since 1990 the requirements of tractor users have been shaped by numerous factors such as increases in farm size and greater geographic spread of farmed land; significant labour force reductions and a consequent need for greater productivity per man, and of course changes in agricultural practices, frequently to permit a farming business to continue with reduced inputs. Finally, we should not forget the vagaries of 'fashion'.

So how has tractor design changed to meet these requirements? Since 1990 we have witnessed a linear increase in UK average new tractor engine power, from approx. 100 hp to over 160 hp today. Whilst the 'all-purpose' farm tractor of 1990 perhaps had 100 hp under the bonnet, today we are more likely to find 200 hp.

The period has witnessed the progressive dominance of four-wheel drive (4wd) tractors across virtually all power ranges and a dramatic increase in the max road speed capability of 'conventional'- design tractors (from ~20 mph to ~30 mph), the latter facilitated by the introduction of front axle and cab suspension systems.

Front 3pt linkages and front P.T.O.s are now commonplace on many medium – large tractors, enabling use of combined front and rear-mounted implements. This improves utilisation of available (higher) engine power, but has also necessitated increases in vehicle payload capability and structural strength. Front 3pt linkages also provide a convenient way to pick up those increasingly-large front ballast weight packs, which also seem to be evolving into storage boxes and front bumpers!

When viewed externally, today's tractors seem to be larger, more powerful, faster and heavier: developed with the aim of getter greater output from fewer operators. However, despite this evolution today's tractor is still required to be a multi-purpose vehicle: after all it can do nothing without an attached

implement.

The last 30 years has witnessed the increasing popularity of dedicated, self-propelled agricultural machines, not just for crop harvesting, but also for agrochemical application and materials handling purposes. Whilst very popular in the UK, telescopic handlers have failed to displace tractor-front end loader combinations from the marketplace: consequently the convenient installation and use of increasingly-powerful front loaders remains a significant influence upon modern tractor design.

So if this is an overall view of tractor evolutionary change during the period, what actual technological developments have occurred in agricultural tractor design to permit these changes?

POWERPLANT

The diesel engine has retained dominance as the tractor powerplant of choice, but perhaps change is on the horizon? It is however certain that, over the last 30 years, Off-Road diesel engines have enjoyed more developmental resources and have consequently demonstrated greater physical change than many other tractor components.

Many of these developments have been driven by progressively-tighter regulatory requirements intended to limit environmentally-polluting engine exhaust emissions. Since the mid-1990s these measures have been extremely successful in reducing emissions of oxides of nitrogen (NO_x) and particulates from tractor diesel engines, but not without the addition of both extra cost and complexity to the powerplant.

Initial pollutant reduction targets were met by increasing fuel injection pressures, more precise control of fuel injection volumes and timing, and wider use of turbocharging. More stringent requirements prompted the adoption of high-pressure 'common-rail' fuel injection equipment and exhaust gas recirculation systems, both of which were facilitated by the availability of microprocessor-based electronic engine control systems, derived primarily from the automotive vehicle sector.

Yet tighter restrictions resulted in the move to exhaust-mounted diesel particulate filters (to trap and combust unburnt particulate matter) and catalytic reduction systems, the latter which utilise urea solution (e.g. AdBlue) to reduce NO_2 emissions.

These systems represent a significant change from tractor diesel engine technology of the late-1980s and have introduced many associated challenges, not least the problem of trying to find adequate space on the vehicle to accommodate pieces of (frequently very hot) equipment. Nonetheless it is important to appreciate that these systems and the environmental benefits which they deliver could not have been introduced without the presence of reliable and readily-adaptable electronic control systems.

So has tractor powerplant development over the last 30 years been focused solely on reducing environmental emissions? Well almost but not quite. The introduction of intelligent engine control systems, higher-performance fuel injection equipment and related features has significantly increased the power density of modern diesel engines, i.e. the power level which may be reliably produced by an engine of given cubic capability.

For example a typical 4-cylinder turbocharged tractor engine of the 1990s may have generated approx. 100 hp, whereas today 160 hp is commonplace. The torque reserve characteristics of modern tractor diesel engines are also vastly superior to those of their predecessors; most now actually demonstrate a rise in engine power output as engine speed reduces from rated (maximum) speed. Consequently the engine no longer has to be operated 'flat-out' to obtain maximum performance. However, there are many who miss the sight of a plume of black exhaust smoke as an indication that the vehicle is being worked sufficiently hard!

POWERTRAIN

Whilst free of regulatory influence, many progressive (if not revolutionary) developments have come to the marketplace in this area over the last 30 years. Operators have always wanted the ability to select the most appropriate gear ratio for the task in hand with the minimum of restriction. If / when the tractor's loading level changed, the operator wanted to be able to change gear, on-the move, under-load.

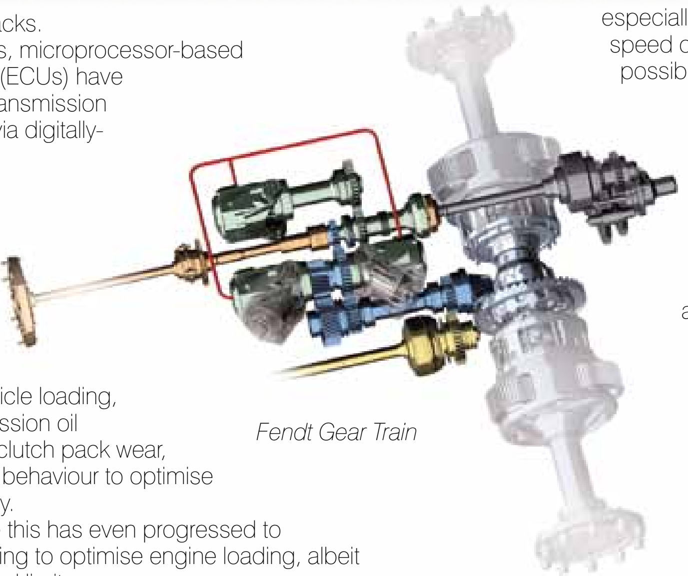
30 years ago stepped-ratio 'Semi-Powershift' and 'Hi-Lo' transmissions were the norm. Over time the number 'shift-under-load' gear ratios offered by agricultural tractor transmissions increased from 4 to 6 or even 8 within the 18 or 24 ratios present in the gearbox: additionally a powershuttle / power-reverse feature was usually provided to enable clutchless directional changes. The next progressive development was the widespread adoption of 'Full-Powershift' transmissions enabling shifting under load between all transmission gears.

Again, not a new concept by any means, but now probably the standard transmission for larger (above 175 hp) tractors.

It's perhaps not readily-appreciated that electronic control systems play an absolutely critical role in the operation and control of modern tractor transmissions and provide many of the vehicle features we enjoy today. All powershift transmissions rely upon sequenced engagement / disengagement of hydraulically-actuated

multiple-plate clutch packs.

Since the early-1990s, microprocessor-based electronic control units (ECUs) have been used to control transmission clutch pack operation via digitally-operated electro-hydraulic control valves. These intelligent control systems are able to monitor numerous other vehicle characteristics e.g. vehicle loading, shaft speed(s), transmission oil temperature and even clutch pack wear, and adjust their control behaviour to optimise transmission shift quality.



Fendt Gear Train

Over the last decade this has even progressed to automated gear changing to optimise engine loading, albeit within operator-controlled limits.

The other major change in tractor transmission technology during the period has been the widespread adoption of 'power-split' CVTs (Continuously Variable Transmissions). The CVT's ability to control vehicle speed steplessly, largely irrespective of engine speed, is every tractor driver's dream.

Hydrostatic transmissions also permit this, but unfortunately their poor mechanical efficiency makes them unsuited to heavy draught operations. The power-split CVT combines the mechanical efficiency of a stepped-ratio driveline and the variable-ratio capability of a hydrostatic transmission in a union made possible by intelligent electronic control. Power flow from the engine is split, part being routed via a mechanical driveline and part via a hydrostatic branch, before being re-combined to drive the wheels.

The proportion of power flow through each 'branch' depends upon vehicle speed and the number of (automatically-shifted) mechanical gear ratios incorporated. The German manufacturer Fendt were responsible for bringing the concept to the market: today CVTs are offered as an option on larger, higher-spec. tractors by all major manufacturers.

DRIVER COMFORT

The importance of ensuring tractor driver comfort, to maintain productivity throughout long working days, had long been recognised. Consequently developments in this area primarily involved the commercialisation of concepts already well-proven by researchers in the UK and elsewhere.

Front axle and cab suspension systems are two ride vibration reduction features which have moved from 'novelty' to almost 'standard', especially if the tractor has a high max speed capability. Indeed today it is even possible to control suspension system characteristics electronically via the operator's in-cab 'Virtual Terminal' display.

These systems, together with advanced suspended operator seats, cab air-conditioning systems, Bluetooth-linked mobile phones and a progressive reduction of in-cab noise levels, have served to improve driver comfort on medium – large tractors to levels few would have imagined. The only slight drawback is that some vehicles are now so large that climbing into the cab seems like a mountain ascent.

VEHICLE CONTROL SYSTEMS

There is nothing revolutionary regarding the use of control systems on tractors, but the evolutionary establishment of microprocessor-based electronic control systems over the last 30 – 40 years, replacing and/or augmenting their mechanical or hydro-mechanical predecessors, probably represents the single largest development of the period.

Electrohydraulic implement draught control systems were offered by many tractor manufacturers during the 1980s, but during the 1990s electronic control technology was applied both to tractor engines and transmissions. This not only delivered improved system behaviour and a range of new features; it also generated a whole host of additional vehicle

system data which was ripe for further utilisation.

The adoption of vehicle digital communication network (CAN Bus) systems during the early-2000s enabled this data to be shared readily around the tractor and also (potentially) to any attached implements. Similarly, implement sensor data could be utilised by the tractor's control systems. The ISOBUS system was introduced to provide ready electronic interconnectivity and data exchange between tractors and implements.

However, to-date, lack of thorough system standardisation across the industry has prevented the concept's full potential from being realised. Whilst tractor manufacturers are prepared for in-cab operator displays to be configured to show implement-related data and controls, the concept of the implement controlling tractor functions seems to be less attractive. In today's litigious society, perhaps this attitude is understandable.

GPS-based tractor auto-steer / auto-guidance systems are another significant commercial development of the period. Once again facilitated by the tractor's network of electronic control systems, such technology now permits not only accurate straight-line driving and in-field positioning, but also the automation of tractor-implement headland turn operations.

CURRENT ISSUES & FUTURE PROSPECTS

The modern tractor has improved significantly in many ways.

It remains a fairly effective all-purpose 'compromise' vehicle, but there are many areas in which further improvements can be made. Over recent decades users have placed emphasis on reducing labour input and increasing worker productivity, but perhaps not upon operational and energy efficiency. Larger, heavier, more powerful tractors and implements enable us to perform tasks quickly with textbook timeliness, but perhaps not so efficiently and also possibly in conditions when we should know better?

Do we inadvertently damage the soil with large vehicles, but cite subsequent reparative operations as justification for their use? Are tractor operators (and their managers) becoming progressively more remote from that delicate natural environment upon which agriculture depends?

The adoption of vehicle-based intelligent control systems has done much to optimise tractor-implement performance and provide appropriate information to the operator. It also provides an essential platform to support machine – farm office data connectivity: a vital tool in minimising the administrative burden associated with environmental compliance, which is unlikely to reduce in the future.

Overall, this technology can offer further significant improvements in tractor-implement operational efficiency.

However field-scale agriculture remains compelled to operate in the variable and unstructured environment which is the UK countryside.

Whilst the latter's characteristics are dictated primarily by Nature, its treatment is influenced by environmental (and therefore political) opinion. This is unlikely to change, so any future replacement(s) for tractor-based agriculture will be compelled to operate within these constraints. Will future taxpayers be prepared to accept changes to the countryside if these are a pre-requisite of cost-effective agricultural automation?

Will we witness the advent of autonomous, field-scale robots? The necessary technology will undoubtedly be developed, but I question the overall economic viability of the concept and believe adoption will be dramatically slower than its proponents may predict.

Agriculture is conservative in nature; we need to cover large field areas quickly in increasingly limited weather windows and every season many hundreds of tonnes of produce must be moved from field to every farm store.

Improving energy efficiency and minimising environmental impact will remain prime objectives. Agricultural vehicle engineers will continue to make advances by adopting and/or adapting technologies made cost-effective by the automotive and consumer goods sectors.

Hybrid and/or electrically-powered vehicles will potentially displace smaller tractors in certain applications.

Our ability will continue to be measured by the degree of success with which these future solutions can accommodate the huge variety of activities and operating conditions which define UK agriculture.

Images courtesy of CNH Industrial, Deere and Company, CLAAS GmbH and AGCO GmbH

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DOUGLAS BOMFORD TRUST

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The Trust was founded as a registered charity in 1972 in memory of Douglas Bomford, agricultural machinery entrepreneur, former President of IAgrE and driving force behind the creation of the National College of Agricultural Engineering (now part of Cranfield University)**.**

The Trust's aim is to help advance knowledge, understanding, practice, and competence in applying engineering and technology to achieve sustainable agricultural, food and biological systems, for the benefit of the environment and mankind, by providing funding and contributing to a wide range of activities, including:

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TRAVEL SUPPORT (Shows, study tours, conferences in UK and overseas)

MONITORING AND MENTORING

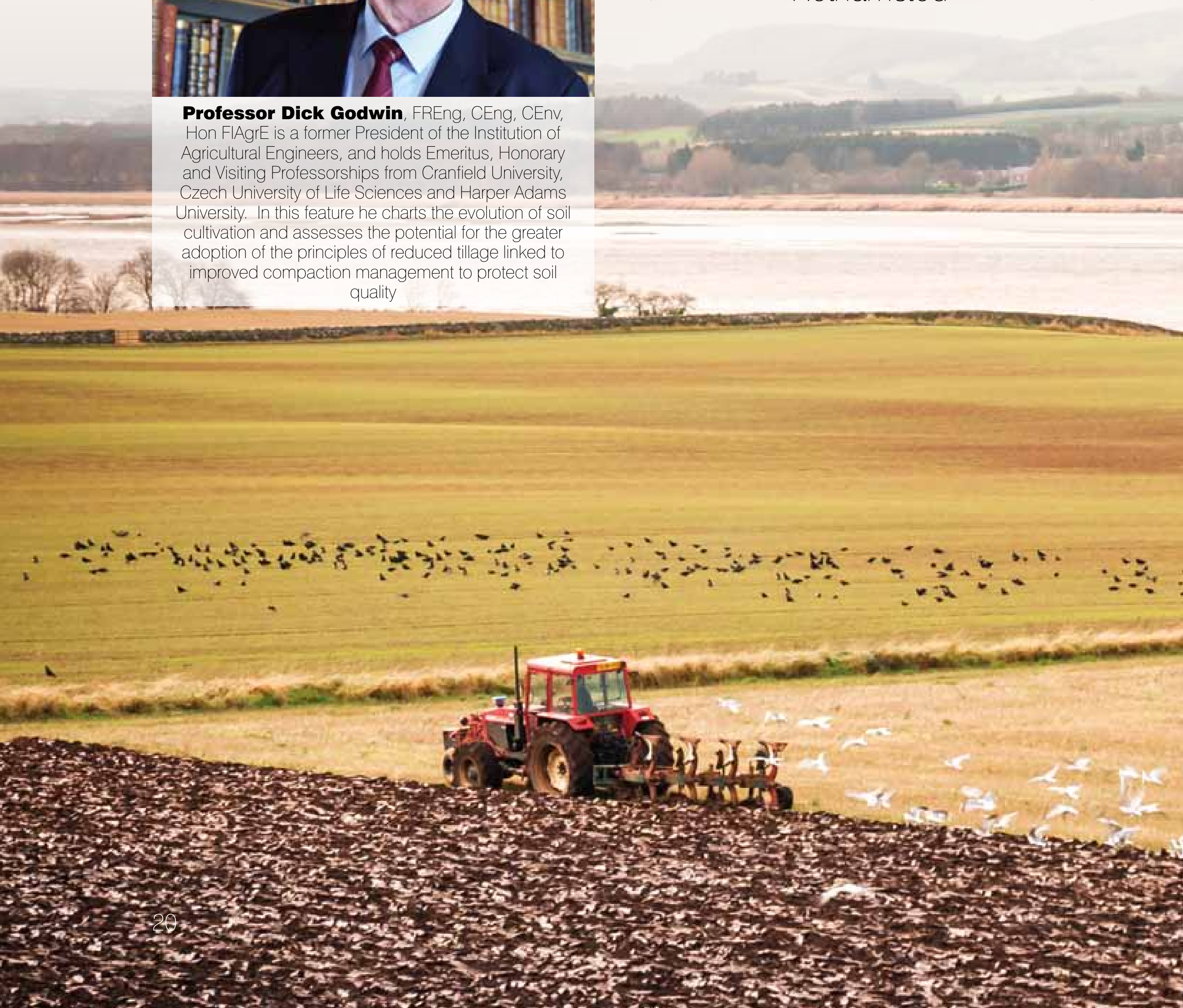
SPECIAL PROJECTS (Agricultural engineering building and DBT Lecture Theatre)

and much more . .

CULTIVATION AND TILLAGE

Professor Dick Godwin, FREng, CEng, CEnv, Hon FIAgrE is a former President of the Institution of Agricultural Engineers, and holds Emeritus, Honorary and Visiting Professorships from Cranfield University, Czech University of Life Sciences and Harper Adams University. In this feature he charts the evolution of soil cultivation and assesses the potential for the greater adoption of the principles of reduced tillage linked to improved compaction management to protect soil quality

> ***"Agricultural crops are far more sensitive to weeds than to tilth."***
> *E. W. Russell, 1945. Rothamsted*



Let us first consider the purpose of tillage, which is to provide a soil environment that will enable: -

- The establishment and subsequent development of a crop by providing adequate consolidation and porosity for seed germination, root growth, gaseous exchange and water infiltration,
- The management of residues from earlier crops, and
- Weed control.

Before the introduction of effective herbicides the most effective method for achieving these objectives was the use of the mouldboard plough, which was developed in Europe with our relatively benign climate. In the hands of a skilled ploughman all of the surface residues and weed population could be buried in the soil profile between 125 and 250mm deep.

Often the resulting tilth and levelness, especially with stronger clay soils, would be too coarse and rough for a seedbed, and where over winter wetting and drying and freezing and thawing cycles were insufficient to reduce the clod size then "secondary" tillage practices would be required. These would consist, over the years, of rigid and spring tines; disc, drag, rotary and reciprocating harrows; and furrow presses that would reduce the coarseness of the tilth and reduce the surface roughness.

Whilst the plough managed the weed population prior to crop establishment it was the advent of the seed drill by Jethro Tull in 1731, which planted the crop in rows that enabled inter-row hoes to be used to reduce the weed burden in the growing crop.

Prior to the availability of mechanical power for these operations the major draught operations were conducted using animals, primarily horses. Steam-powered traction engines were introduced in the second half of the 19th century. Whilst these were heavy (c.20 tons) they caused little soil compaction as they were generally worked in pairs, with one each side of the field and a reversible "balance" multi-furrow (often 5) mouldboard plough winched between them. The use of winch cables also enabled more of the available engine power to be used for cultivation purposes enabling work rates of c.30 acres/day. One contractor in Suffolk was using this system into the 1970's.

TILLAGE TECHNIQUES

In the period between the two world wars, leading up to the time of the formation of the IAgrE in 1938 lighter internal combustion engine powered tractors (10 to 40 hp) were replacing horses at the rate of 1:10. Data from the East of England, however, indicates that the actual substitution rate was lower than this, as many horses were kept on the farm.

The tractors could directly pull 1 to 3 furrow mouldboard ploughs, and were initially directly hitched via a simple pin to the tractor drawbar. However, it was at this time that Harry Ferguson was developing a major tractor advance, namely the "3 point hitch" where ploughs and other implements

Jethro Tull Drill


Vaderstad Topdown

could be fully mounted directly on the rear of the tractor, which would control their working position, depth of work and ultimately draught force.

This mounting provided the added advantage of weight transfer directly from the implement, and from the front (generally non-driven) tractor wheels to the rear driven tractor wheels as a result of the plough forces acting on the tractor. Thus improving the tractors ability to pull implements with higher draught force requirements.

While the use of the mouldboard plough provided a very good solution in the benign European climate it was to cause serious problems in harsher conditions, and is frequently blamed as a contributing factor in creating the dust bowl conditions in the USA in the 1930's. As a result tillage techniques were developed which did not completely invert the soil but left the majority of the residues on the soil surface to protect the soil from erosion.

In the 1960's the use of the chisel plough (tine based tillage at depths of 125-200mm) gained popularity in the UK, as it was faster and did not require the same level of skill to operate as the mouldboard plough. For similar reasons heavier duty disc harrows were also becoming available, hence the concept of "reduced tillage" or "min-till" was established. Initially these tools were used independently but later developments integrated them into the same implement.

The trailed "Tillage Train" which consisted of tines to provide the initial penetration and "soil shatter", followed by discs, which cultivated a shallow depth of soil whilst incorporating crop residues. Many similar concepts followed to which could be added the options of deeper subsoiler tines and roller presses.

DIRECT DRILLING

The move to reduce tillage was assisted by the introduction of Gramoxone (paraquat) in 1962, a contact non-systemic herbicide that left no-residues; which when sprayed on to the weeds effectively replaced tillage for weed control. Roundup (glyphosate), being systemic was more effective, and subsequently overtook Gramoxone. These herbicides assisted in the development of "direct drilling" or "no-till" crop establishment techniques and the equipment to perform less invasive tillage operations, so saving energy and time and potentially improving the soil environment.

During the late 1960's and 1970's a very significant amount of research was conducted on these techniques in the UK to quantify the impact on crop yield, soil conditions and the potential economic benefit. A major nationwide study combined the results of 214 site x years crop yield data to produce a nationwide map. This considered both the soil type and climatic conditions where the expected crop yield from direct drilling was either similar to or less than conventional plough based tillage for both autumn and spring sown crops.

A limitation occurred with compacted sandy loam soils, which do not produce the natural surface tilth and deeper cracking by shrink - swell action on drying and wetting in the way that many clay soils do. As a result the "Paraplow" was designed to loosen the compacted soil, leaving a level surface with little or no surface clods. This came into use alongside a number of other deeper loosening tools (subsoilers) to repair the soil damage caused by heavier equipment identified in the Strutt Report (1971) following the very wet harvest of 1968.

Initially during this period the crop residues were less of a problem, as the common practice was to burn them in the field, often removing not only the cut straw but also the standing stubble. However, for good environmental reasons the practice of straw burning was phased out in the early 1980's. As a result, germination problems associated with the products of decomposition of straw residues pushed into the seed slots caused primarily by disc type drills (so called "hair-pinning") became more significant. This was exacerbated by increases in straw yields and wider combine header widths when straw choppers and spreaders were still in their infancy.

As a result of this and grass weed problems the uptake of both direct drilling/no-till and reduced tillage practices, in the UK, waned from the early 1980's with conventional plough based techniques regaining popularity to some 90% of the primary cultivation method. During this period, combination tools consisting of a power harrow and seed drill became popular, these effectively combined both the secondary tillage operations and the seed placement in one operation so improving timeliness and reducing labour costs.

The main reasons for a farmer to consider reduced cultivations are to:

- Reduce energy consumption,
- Save time and reduce labour costs,
- Conserve soil moisture,
- Retain plant cover to reduce erosion.
- Minimize machinery costs, and
- Minimize the loss of organic matter.

It has also been suggested that farmers new to direct drilling/no-till farming must learn to be patient and to postpone the operations until the soil conditions are right. This is fine whilst waiting for rain in a dry autumn but less appealing in wet autumn soil conditions.

A small sample of no-till farmers surveyed for the Worshipful Company of Farmers reported that weather/

soil conditions made a difference, stating that the system worked better in dry conditions. With one farmer arguing that it is the best practice in all conditions as it is the long - term benefit of farming with undisturbed soils that is the key to success. The farmers reported that they had saved costs, improved the soil environment and had more time with the family.

The current resurgence in direct drilling has been made possible by improved machines with:

- A greater adoption of tine drills rather than disc drills,
- Tine mounted wing components that place the seed on a "bench" rather than in the bottom of a smeared slot hence easing the problems arising from hair-pinning, and
- Improved straw chopper/spreader performance at harvest.

COMPACTION MANAGEMENT

Key to the success of all tillage operations is compaction management and so field operations should be conducted with the minimum of vehicle weight, low tyre and track contact pressures and the fewest number of vehicle passes.

Following earlier work in Scotland, studies in the Czech Republic showed that 85%, 65% and 45% of the surface area of a field were covered by wheels/tracks in a single growing season with conventional plough based tillage, reduced tillage and direct drilling respectively. Hence the use of rubber tracks and lower inflation pressure tyres that meet the inflation pressure requirements for both field and road conditions and "controlled traffic farming (CTF)" offer significant advantages.

CTF systems can reduce the trafficked area from the numbers given above to approximately 30% and possibly down to 15%. The latter is achieved in Australia where there are no width restrictions to tractor wheel spacing widths, where they can be extended to match those of the combine harvester.

WEED CONTROL

Currently the weed control of black-grass (slender foxtail), a weed of poorly drained clay soils, is giving concern as herbicide control and the timing of spray applications become more difficult. Tillage related activities could help by:

- Delaying the crop establishment operation to give additional time for further herbicide application,
- Burying the surface weed seeds with a mouldboard plough, ensuring that the plough skimmers are set correctly to place all seeds and residues in the furrow bottom. Followed by shallower tillage practices in subsequent years to reduce the risk of returning the weed seeds to the surface.
- Considering the adoption of low cost drainage options, such as mole ploughing directly into an open field ditch or into deeper "mole mains" to improve drainage. This solution has merit with short-term land rental, where neither the landlord nor tenant wishes to invest in full cost drainage work.

Aside from the traditional methods, new precision weed control practices are emerging, which promise to reduce herbicide usage and the need for hand weeding. In higher value crops, like lettuce and cabbages inter- and intra-row weeding with mechanical hoes controlled by image analysis techniques that differentiate between the weed and the crop are being adopted.

Image analysis is also enabling developments in the targeting of weeds by directing a laser beam to the meristem of any offending weeds at an early stage in their growth or by squirting a precision jet of herbicide only on to the weed. These techniques have very significant environmental advantages by eliminating the need for herbicides or reducing the quantity applied to a very low level.

THE FUTURE

So what of the future? Crystal ball gazing is always problematic but the logical next developments are: -

- A greater use of "direct drilling/no-till" and probably "strip tillage" which has the advantage of combining a restricted zone of tilled soil to help establish the crop plus the benefits of direct drilling. This, however, will be influenced by the availability of the appropriate herbicides to control the weed problem.
- A greater use of "controlled traffic farming" principles,
- Linking the use of autonomous or semi-autonomous vehicles with CTF,
- The adoption of targeted sprays and lasers for selective weed control, based upon autonomous or semi-autonomous vehicles,
- Greater strategic thinking and planning on behalf of farmers and advisers to devise a practical system that works for their soil conditions. Linking these to the requirements for both environmental and economic sustainability.

Acknowledgements

I would like to thank Brian Finney and Professor Gordon Spoor for their advice in the preparation of this article and unstinting support for the past 50+ years.

THE LANDBASED TECHNICIAN

From the blacksmith's shop to a computer-laden agri-tech service centre, the role of the landbased technician has changed out of recognition during the past 80 years. Former IAgrE President **Peter Leech** HonFIAgrE, who spent 42 years with John Deere UK in senior training and customer support roles, examines the march of progress

The land-based technician role is one that has evolved through many stages as technology has developed into a role that bears little or no resemblance to its origins.

In the very early days of agricultural mechanisation, everything was essentially made by the blacksmith. This was typically a local facility where hand tools, harrows and simple implements were made for horses to pull and of course, the blacksmith was responsible for shoeing the horses too. So all the farmers' needs were met by the local blacksmith and when their implements needed repair or renewal they simply went back to the local blacksmith.

The blacksmith could design (usually with chalk on the floor), manufacture, repair and modify essentially any implement on the farm. Most of today's farm equipment manufacturers started from small beginnings in a blacksmith's shop, even the major international companies like John Deere. Many implements are still made on a bespoke basis by local blacksmiths who are today more like fabricators rather than traditional blacksmiths with a forge.

As mechanisation progressed, the age of steam arrived on the farm with large ploughs and cultivators pulled by steam engines (usually on cables) and new and larger barn machinery such as threshing drums and stationary balers driven by belts from the steam engines.

These machines required repair and maintenance but were essentially very simple and a blacksmith with common sense and simple tools could still do most of what was required. Hence, the term journeyman came into being; a journeyman was employed by the blacksmith or the equipment manufacturer and was a basic fitter who travelled to where a machine needed repair, since in most cases the machine could no longer be brought to the blacksmith's forge.

SERVICE VEHICLES

It was around this time and for this reason that travelling to an agricultural machine in the field to perform repairs began and has become generally accepted as the norm in agriculture. Today's technicians operate from service vehicles run by the dealerships and carry out repairs on site. This is one key difference to the technicians who today repair cars, trucks and other types of vehicle which are brought to the technician in the workshop.

During the steam era the term "fitter" became quite widely used as a name for the journeyman who came to repair the steam engine or other machines. This name came from the railways and really implies a person who fits parts, it gives no credit for the powers of deduction in diagnosing a problem

and the ingenuity in developing a repair based on what was available at hand to get the machine running.

Eventually the internal combustion engine took over from the steam engine on the farm in the form of very simple tractors. As these were usually manufactured a long way from where they were being sold (most early ones came from the USA) then the era of specialist dealers came into being.

These were businesses (often owned by blacksmiths) which were set up to sell and support these machines as well as an ever broadening line of more ingenious machines that were being developed for cultivating, sowing, harvesting and processing farm crops.

The technicians working from these dealerships continued the now normal practice of travelling to the farms to service and repair the new tractors and machines; and the term generally used for these technicians was "mechanic" as well as "fitter" which continued.

DIAGNOSTICS

Spool forward fifty years and two world wars to a point where tractors and agricultural machines were developing fast and much more technology was employed. This is the time that professionalism in our industry had started to come to the fore with the IAgrE having been formed in 1938.

It came about in recognition of the rapid development of farm mechanisation and the professionalism of the people involved in making it happen. This included the fitters and mechanics (technicians) at the front end keeping it all working and always has included them.

The diesel engine and tractor/implement hydraulics were probably the two most important advances at this time, both of these brought new requirements for the agricultural technician. It was no longer enough to use common sense and logic in diagnosing problems (although still required in abundance) but now training was required on how the systems worked, how to test and diagnose as well as repair and adjust them.

Manufacturers had to develop comprehensive workshop manuals and training courses to support the mechanics in maintaining these machines. In addition, this ushered in the need for formal apprenticeships, the agricultural colleges stepped up as well as the industry as a whole in developing curriculum, and courses to deliver them.

Several methods of delivery were tried and the block release system of training soon won out as the most practicable. This means the apprentice technician attends one month per term (three months per year) at college over a three year period with the rest of the time on the job

ABOVE: *A typical blacksmiths forge manufacturing and repairing everything for the farm*

working with a qualified technician back at the sponsoring dealership. This also allowed the colleges to organise their academic year around the three year apprenticeship with three year groups coming into college in one month blocks.

This all added to the professionalism and the need for skills and status to be recognised through qualifications and IAgrE membership.

Tractors and machines developed rapidly during the 60's, 70's and 80's with the machines generally getting much larger and more productive. Systems and technology continued to increase with the focus on electrics and electrically operated hydraulics and sophisticated transmissions systems like powershift and IVT. This era also saw the introduction of other technologies such as air conditioning systems, hydrostatic drives and the beginning of electronics. Technicians required more and more training and specialist diagnostic tools to be able to look after these machines but apart from the apprenticeship, there were no further qualifications or recognition available. In addition, they continued to be known as fitters and mechanics, which was becoming rather derogatory in the modern era considering the level of knowledge and skill they required.

LEFT: *Chris Whetnall CEO of IAgrE (1999 to 2013) as apprentice for Penfolds of Arundel in the early 1960's*

SKILLSETS

There were many other engineering disciplines who needed the same skills as the agricultural engineer and many of them made attractive options to earn more and have a somewhat less stressful and seasonal life. These included the oil and gas industries, aeronautical, automotive and construction industries. Therefore finding, training and keeping good agricultural technicians became a real problem to the industry during this time.

The skillsets that were and remain very attractive to others

are; self-sufficiency (working alone on site), adaptability, ingenuity, common sense and a broad knowledge of many different technologies and systems. Also the ability to work directly with the customer and his staff and manage their expectations often under stressful time pressure. And not forgetting a good understanding of agriculture and what the customer is trying to achieve with the machine, its seasonal criticality and need for adjustment to differing soil and crop conditions.

These skillsets and the demand from other industries for them created a serious shortage of technicians in the land-based industries during this time, which continues to some degree to this day.

Various initiatives took place in the 90's to try to focus on this industry-wide problem and develop actions to improve it. One was the Careers Project, which focused on communication and recruitment of new talent with many activities focused around young people and schools.

Another was the development of manufacturer sponsored apprenticeship programmes where the larger machinery suppliers developed their own bespoke apprenticeship programmes covering the national curriculum but adding much more content concerning their products and company procedures, ethos etc.

The first of these was developed by John Deere but within a few years most leading manufacturers had similar programmes working with specific colleges. These were very successful and that success continues today.

From a technical perspective, everything changed up a gear in the 90's and into the new millennium. The electronic age reached agriculture and made a huge impact. This meant yet more to learn for the technician in addition to everything that had gone before.

There were more and more systems added to tractors and machines including electronic control management of each of them individually. In addition, inter-system communication with CAN bus communication came into play and yet more new and advanced technologies were

During the steam era the term "fitter" became quite widely used

ABOVE: *A typical modern day Master Technician with all the tools and technology as well as his name and LTA qualifications on the door*

SKILLS AND COMPETENCES	Pre 1900 Blacksmith	1900 - 1940 Journeyman	1940 - 1970 Fitter	1970 -1990 Mechanic	1990 to Today Technician	The Future Tech of Tomorrow
Practical common sense and logic	X	X	X	X	X	X
Ingenuity to solve problems	X	X	X	X	X	X
Adaptability to invent solutions	X	X	X	X	X	X
Self-sufficiency (working alone on site)		X	X	X	X	X
Customer relationship management	X	X	X	X	X	X
Good understanding of farming operations	X	X	X	X	X	X
Work with steel and welding	X	X	X	X	X	X
Work with spanners and hand tools		X	X	X	X	X
Understanding and working with IC Engines			X	X	X	X
Transmissions			X	X	X	X
Complex transmission systems PST, IVT				X	X	X
Hydraulics, hydrostatics				X	X	X
Air Conditioning systems					X	X
Electro Hydro systems					X	X
Electronics, CAN bus systems					X	X
Emissions systems					X	X
Telematics					X	X
Robotics						X

added. The most significant of these being GPS starting with mapping and monitoring but soon developing into auto steering and prescription control of seeding, spraying and fertilising.

We have since seen the addition of telematics which has enabled remote monitoring and even remote diagnostics.

From the technician's point of view this means that he or she is now a truly high-level technician being trained and skilled in all these multi-facetted systems and interactions, the daily use of electronic diagnostic equipment in addition to all the prior knowledge and skills of his or her predecessors. See the chart, previous page, which tries to demonstrate how the skills and competences required have developed and increased over the past hundred plus years.

ACCREDITATION

In recognition of this ever-increasing requirement for skills and competencies, the industry led by the manufacturers' training managers, in the form of the AEA Training & Education committee in conjunction with IAgrE and BAGMA, developed the Land-based Technicians Accreditation (LTA) Scheme, which was launched in 2005.

This scheme accredits the training provided by the manufacturers and recognises the skills and experience gained by the technician to the point of certifying four distinct levels of attainment and thus providing a career path for qualified technicians post-apprenticeship. The highest level known as Master Technician recognises the top level of the modern landbased technician.

This is the individual that given sufficient information and tools could diagnose and repair any equipment found on the modern farm. The IAgrE managed the scheme and a new body was formed providing overall governance and direction for land-based training. This body is made up from the three main organisations in the industry with an interest in technician training and development these being BAGMA (the dealers' association), AEA (the manufacturers' association) and IAgrE. This body is known as LE-TEC (Land-based Engineering Training & Education Committee).

So what will the technician of the future be like? That of course depends on the technology and mechanisation on the farm but it is likely he or she will be more and more involved with electronics and telematics as they relate to the machines we know but also in relation to robotic equipment. One big difference is that this could mean there will be no operator to quiz and discuss the symptoms of any problems to assist with diagnostics and even more reliance on error codes and the studying of telematics recordings of functional performance.

There will probably be a lot less spanner work repairing engines and transmissions as machines could well be smaller and predominantly driven with electric motors. Another change this could bring about is that the technician may well spend less time on the farm and more time in the technical communications centre and workshop at the dealership.

The one thing for sure is that the land-based technician has played a key role in the mechanisation of agriculture and the position is one that is highly respected by all who work with them.

The name technician is definitely the only one appropriate for these highly skilled and trained personnel.

While technology will undoubtedly continue to develop, there will always be a need for the logical thinking and adaptable people that keep our agricultural equipment moving, The Technicians.

BELOW: *No operator to quiz about the performance of a robot machine*

Meet a Member

ALEXANDRA COOKE CENV MIAGRE

Alexandra (Alex) Cooke works as a Catchment Management Scientist for Severn Trent Water (STW). She gained a PhD at Cranfield University, and in 2016 became a Chartered Environmentalist (CEnv). Alex is a Council Member of IAgrE, and a member of the British Society of Soil Science (BSSS) where she also tutors on the 'Foundations in Soil Science' professional course.

Working for STW involves very diverse, often challenging work, but is always enjoyable and rewarding. I work within the Catchment Team, drawing on my scientific and engineering skills for strategy development and implementation, to ensure that we meet our regulatory targets and provide clean water through cost-effective means for our customers.

The majority of my work involves working with the agricultural sector, with the focus on mitigating the impacts of diffuse pollution whilst ensuring that our farmers remain productive and competitive. As such, much of my work involves the design and provision of products and solutions for our farmers to use in-field, which will produce catchment-scale water quality or biodiversity benefits. Examples include relatively conventional soil erosion prevention and wetland design, through to proactive technology solutions to better engage with farmers across our region.

Every day is different and I love the fact that I'm constantly learning and drawing on a wide skill set – something which I've gained over time. My PhD developed a field-option to mitigate the impacts of diffuse losses, and before this I worked as an Environmental Soil Scientist on projects across the agricultural, utilities, energy and development sectors.

Some people would say I'm not an agricultural engineer – I don't know much about machinery. However, I believe that I represent the modern-day agricultural engineer – someone who works on land-based systems, using science and engineering skills to ensure that the needs of the many are met sustainably and efficiently.

IAgrE AND CRANFIELD UNIVERSITY

Professor Leon A. Terry
FIAgrE
Director of Environment and AgriFood, Cranfield University

Cranfield University and the Institution of Agricultural Engineers (IAgrE) both recognise how agricultural engineering research and training can address the global challenges of food supply. Cranfield has strong and long-lasting ties with the IAgrE, dating back to the establishment of the National College of Agricultural Engineering (NCAE) at Silsoe, Bedfordshire in 1962.

The NCAE was set up to provide a national centre for the agricultural engineering industry, and to educate agricultural engineering students from the UK and overseas. In 1975, the NCAE became part of the then Cranfield Institute of Technology, now Cranfield University.

The IAgrE headquarters moved to the Silsoe campus in 1974 and when Silsoe College's research and teaching activities moved to the Cranfield campus, the IAgrE relocated there too.

Cranfield has provided research and teaching in agricultural engineering for over 50 years, reflecting the wide remit of the IAgrE from 'seed to satellite'.

This has been underpinned by the University's strong engineering and industrial manufacturing prowess. IAgrE has recognised Cranfield's teaching innovation, excellence and quality through professional recognition of agricultural engineering-related courses as meeting the educational requirements set by the Institution.

The recent resurgence of agricultural engineering is welcomed cf. UK Strategy for Agricultural Technologies (July, 2013), and UKRI's Forward Look for UK BioScience (October, 2018) where 'precision agriculture and smart technologies' is now highlighted. Supported by the IAgrE, Cranfield is a partner in two of the UK Government Centres of Agricultural Innovation – the Crop Health and Protection Centre (CHAP) and the Agricultural Engineering, Precision and Innovation Centre (AgriEPI).

This has brought investment of over £13 million in unique, innovative research facilities at Cranfield since 2016. These purpose-built, state-of-the-art facilities demonstrate the role of agricultural engineering research throughout the food supply chain. To boost agricultural engineering activities further, the University is investing £4 million in a new building and Centre for Environmental and Agricultural Informatics.

Cranfield students and staff appreciate IAgrE's role in bringing together academics, practitioners and industry to promote the profession of agricultural engineering. These collaborations will be essential for the successful implementation of key government policies such as the Industrial Strategy, the Agriculture Bill and the 25-year Environment Plan. Cranfield is committed to working with the Institution to attract talented people into the profession and to support the career development of agricultural engineers throughout the world.

The Institution and University have worked together in changing the traditional image of agricultural engineering by embracing new technologies and approaches to working. Cutting edge research is no longer solely about the traditional engineering of large-scale agricultural machinery, but now includes small-footprint, intelligent and data driven biosystem engineering solutions.

Future developments in agricultural engineering will increasingly cut across sectors and disciplines, often incorporating advances from disparate disciplines (e.g. optics, biophysics, 'omics) to develop technological solutions which are implemented in agriculture to provide additive value to ongoing developments in biotechnology, synthetic biology, soil science, and postharvest bioscience. Agricultural engineering needs to be better integrated with biology.

Primary production and waste reduction targets will not be met by fundamental plant biotechnology alone; a paradigm shift is needed whereby molecular plant science is truly complemented by integrated engineering and digital agriculture. The challenge is to breakdown the misunderstanding and prejudice within each research community so that projects are solution-based.

At present, there is reluctance from many in the plant biotechnology community to truly engage with agricultural engineers and vice versa. With support from the IAgrE, this is beginning to change.

SOIL SCIENCE

Professor Jane Rickson CEnv FIAgrE is Chair of Soil Erosion and Conservation at the Soil and AgriFood Institute at Cranfield University. She has over 30 years research and teaching experience in soil and water engineering, soil degradation processes and land management. Jane is the current President of the Institution of Agricultural Engineers

FROM DUST BOWL TO DNA IN 80 YEARS

The key topic areas of agricultural engineering – land management, forestry, horticulture, amenity, environment, precision farming, power and machinery, animal production, bioresources and land use – all have one thing in common: a connection with soil.

As we celebrate 80 years of the Institution of Agricultural Engineers, how has our understanding and study of this precious, effectively non-renewable, natural resource changed over time?

Eighty years ago, when the Institution was being founded, the most devastating dust storms were ravaging farmland throughout the North American plains.

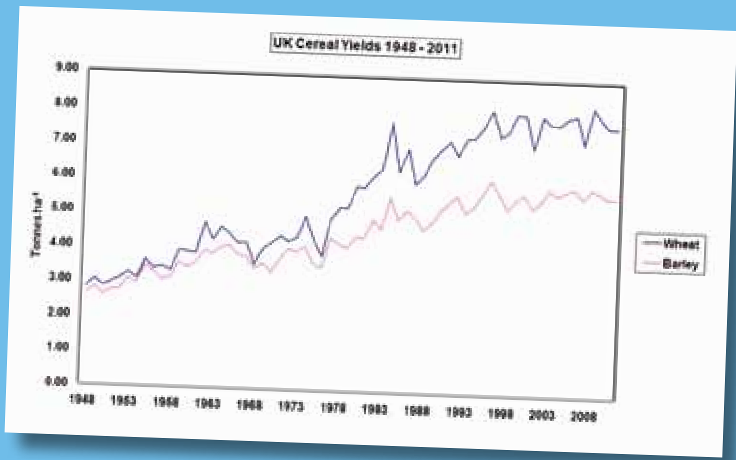
The Dust Bowl saw some of the most destructive soil erosion in recorded history, caused by unsustainable soil management practices and a severe drought that made the soil easily blown or washed away.

Thousands of people were displaced as they could no longer make a living on the land, leading to mass migration and poverty in the cities where the Depression already had a strong hold. This tragic episode in agricultural history did have some positive outcomes, however.

People, including the US Government began to appreciate the importance of soil as underpinning the economic and social foundation of rural livelihoods. People also realised that the management of this natural resource determined whether it would be there for future generations. Indeed, the United States Department of Agriculture (USDA) Soil Conservation Service (originally the 'Soil Erosion Service') was founded as a direct response to the severe soil degradation of the Dust Bowl.

This organisation is now known as the Natural Resources

Conservation Service (NRCS) and it continues to offer advice and support to millions of farmers regarding sustainable soil management practices.



NATIONAL SOIL SURVEYS

In the UK at this time, Gilbert Wooding Robinson (1888 - 1950), Professor of Agricultural Chemistry at Bangor University wrote "Soils, their origin, constitution and classification" (1932), which is considered the first English textbook on pedology. He also happened to be the first Director of the National Soil Survey of England and Wales, founded in 1939. This date is significant: soils were formally acknowledged for their important contribution to the 'war effort'.

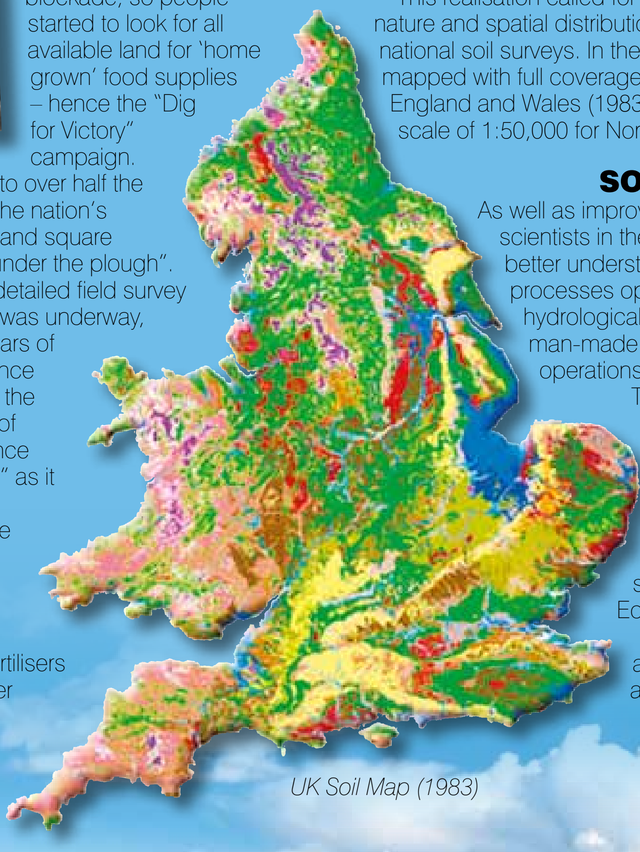
Before the Second World War, 75 per cent of Britain's food was imported by ship, but this was threatened by the German U-boat blockade, so people started to look for all available land for 'home grown' food supplies – hence the "Dig for Victory" campaign. This led to over half the civilian population involved in the nation's "Garden Front", with ten thousand square miles of land being "brought under the plough".

By 1946, an extensive and detailed field survey of soils in England and Wales was underway, representing over 200 man-years of effort. The increasing prominence of soil science continued after the war, shown by the foundation of the British Society of Soil Science (BSSS) in 1947 (or "BS cubed" as it is fondly known).

Scientific support to increase food production from soils continued through the 1950s and 1960s. Soil science research often focused on the use of industrially produced fertilisers (particularly nitrogen and 'super phosphate') and their ability to increase soil fertility and crop yields. Much of this research was carried out at Rothamsted Research Experimental Station in Harpenden, where the Soil Survey Research and Advisory Service was founded.

By the 1970s, soils were seen in a much broader context. Not only did they underpin crop production on agricultural land, they also determined the suitability of land for other uses such as forestry and nature conservation.

This realisation called for better understanding of the nature and spatial distribution of soil resources through national soil surveys. In the UK, soil properties were mapped with full coverage at a scale of 1:250,000 for England and Wales (1983) and Scotland (1984) and a scale of 1:50,000 for Northern Ireland.



UK Soil Map (1983)

SOIL EROSION

As well as improved mapping of soils, soil scientists in the 1970s and 1980s wanted better understanding of the complex processes operating in soils, including hydrological, chemical, biological and man-made interactions such as agricultural operations, tillage and cultivations.

The development of new computer software and hardware allowed analysis of vast amounts of soils data and the creation of a number of empirical models, attempting to simulate soil processes, such as the Universal Soil Loss Equation (1978).

It also became increasingly apparent that whilst greater agricultural intensification had

increased food production over the years, this could have detrimental effects on the wider environment. The potential damage to soil resources from external pressures including agricultural intensification and spreading urbanisation was increasingly recognised in the 1990s.

Processes such as soil erosion by water and wind, soil compaction, loss of organic matter, and loss of habitats not only threatened the ability of soil to produce food, but affected the wider environment, such as the impact of eroded sediments on the quality of aquatic habitats and water resources. Many studies investigated soil as an important carbon sink (store) and source, able to change global carbon fluxes, including CO_2 concentrations in the atmosphere that lead to global warming and climate change.

These complex relationships required better scientific understanding of the soil, atmosphere and vegetation (and their interactions) at global scales and the UK Research Councils (especially the Natural Environmental Research Council (NERC) and the Biotechnology and Biological Sciences Research Council (BBSRC) funded much of this science.

Whilst food production was still a primary 'good' delivered by soil, many other soil-derived benefits to society were identified and valued. For example, in 1997, these benefits were estimated to be tens of trillions of US dollars per year globally, of which at least US $1.5 trillion came from the benefits brought by soil biology alone.

International Decade of Soil 2015-2024

The ecosystem goods and services framework appeared in the EU Thematic Strategy for Soil Protection published in 2006, which became the driver behind much of the applied soil science research in the UK at that time.

By signing up to the Strategy, national governments committed to a) understand the state of their soil resources; and b) where soil degradation was identified, how this would be addressed with policy instruments such as subsidies or support for soil conservation measures to mitigate the damage.

As the key policy driver, the Thematic Strategy instigated a great deal of soil science research into the threats to soil resources, identified as soil erosion, organic matter decline, salinisation, compaction and landslides, contamination and sealing by urban development.

INTERNATIONAL YEAR OF THE SOILS

So what is the state of soil science today and how is this relevant to agricultural engineering?

In his Foresight Report on the future of food and farming (2011), the UK Government's Chief Scientific Officer, Sir John Beddington identified five challenges and choices for global sustainability: food, water and energy security; climate change adaptation; and loss of biodiversity and ecosystems. Looking at *Chart 1*, it is clear that healthy soils can address many of these challenges.

The contribution of soil to society was celebrated when 2015 was designated the International Year of Soils (IYS 2015) by the 68th session of the United Nations General Assembly after recognising December 5th as World Soil Day.

The International Union of Soil Sciences (IUSS) followed this up by announcing the International Decade of Soils to increase the momentum of raising awareness of the importance of soil for life and to put soils and soil science on the global agenda.

It could be argued that the current soil science paradigm is defining "what is 'soil health'?"; and "how can we improve it?"

The former question is driving exciting developments in soil science at a fundamental level, for example, the use of next generation sequencing to understand RNA and DNA found in soil as important indicators of the metabolic status of soil microbial communities.

These are essential in driving nutrient dynamics and thus soil health. The latter question of 'how can we improve soil health' is where the agricultural engineer comes in, by devising technically effective, economically viable and socially acceptable soil management practices to improve the state of our soil. It is encouraging to see that 'soil health' is mentioned explicitly in the UK Government's 2018 '25 Year Environment Plan' and their 'Health

	Ecosystem service	Soil function	Example
Supporting			
1	Primary production	Support for terrestrial vegetation	Support for principle photoautotrophs
2	Soil formation	Soil formation processes	Weathering of rock and accumulation of organic material
3	Nutrient cycling	Storage, internal cycling and processing of nutrients	N fixation and N and P mineralisation and cycling
Provisioning			
4	Refugia	Providing habitat for resident and transient populations	Burrows for soil macro fauna
5	Water storage	Retention of water in landscape	Retention of water in pore network, modulates soil biochemical processes
6	Platform	Supporting structures	Supporting housing, industry, infrastructure
7	Food supply	Provisioning plant growth	Provisioning for crops and livestock for farming
8	Biomaterials	Provisioning plant growth	Producing timber, fibre, fuel
9	Raw materials	Provisioning source materials	Topsoil. mineral, aggregates extraction
10	Biodiversity and genetic resources	Sources of unique biological materials and products	Medical products, genes for resistance to pathogens and pests
Regulating			
11	Water quality regulation	Filtration and buffering of water	Potable water for human consumption and good ecological status of rivers, lakes and seas
12	Water supply regulation	Regulation of hydrological flows	Flood control where surplus, irrigation where deficit
13	Gas regulation	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SOx levels
14	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes	Greenhouse gas regulation
15	Erosion control	Soil and colloid retention within an ecosystem	Retention of soil on hillslopes and in wetlands
Cultural			
16	Recreation	Providing a platform for recreational activities	Eco-tourism, sport
17	Cognitive	Opportunities for noncommercial activities	Aesthetic, education, spiritual, scientific value
18	Heritage	Holds archaeological record of terrestrial occupancy and civilisations	Preservation/destruction of archaeological record

Chart 1

and Harmony: the future for food, farming and the environment in a Green Brexit' consultation paper.

It will be interesting to see how this support for better understanding and protection of soil health is translated into policy. Perhaps this will instigate some new soil science research programmes to provide the evidence to underpin such policies?

Despite this positive outlook of how soil science can inform soil policy, there is some cause for concern.

A number of recent studies have reported the lack of soil science education and training in schools and beyond. Despite soil science engaging with many sectors and organisations on a daily basis: agriculture, forestry, climate change, landscape, planning, heritage, transport, renewable energy, etc., 'soils' are only very briefly mentioned in the 2013 Key Stage 1 and 2 national schools curriculum. (The only statutory requirement was for pupils to "recognise that soils are made from rocks and organic matter").

At the tertiary level, The Natural Environment Research Council identified soil science as a 'most wanted' skills need in the environment sector. "We badly need soil scientists, especially in food and energy security, but also across the environmental sciences sector. The shortage of soil scientists is due to a lack of training courses in the UK.

These skills are crucial for the security of agricultural land and food supply under demographic and environmental change, and for energy security". A quick internet search of soil science degrees shows there are no longer any straight 'soil science' degrees at undergraduate or postgraduate level in the UK.

The closest is the University of Aberdeen's 'Plant and Soil Science' BSc. Worldwide, only New Mexico, Louisiana and North Dakota State Universities, and the Universities of Wisconsin and Saskatchewan run pure 'Soil Science' Bachelor courses.

On a more positive note, soil science research is alive and doing very well. For example, in 2017 Cranfield University was awarded the prestigious Queens Anniversary Prize for its research and education in soil and environmental data.

This is the first time in the Prize's history that an award has been given for soil science.

In the future, soil science as an integral and fundamental part of agricultural engineering has a significant role to play in delivering national and international food security, and sustainable management of our natural resources.

In order to support this contribution, the continuing absence of soil science courses at undergraduate and postgraduate level is of concern (Kibblewhite et al., 2010). Despite this, the professional standing of soil science in the UK is growing.

For example, when the British Society for Soil Science became an incorporated charity in 2010, it merged with the Institute of Professional Soil Scientists and continues to deliver the needs of the Society's professional membership.

Soil scientists who are members of the IAgrE can also gain professional recognition and accreditation as Chartered Environmentalists through IAgrE registration with the Society of the Environment.

The Institution also has a Specialist Group on Soil and Water, holding conferences and discussions on all aspects of soil and water science and engineering.

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ENGINEERING A BETTER ENVIRONMENT

With every challenge comes opportunity. The agricultural engineering sector, one of the most creative and solution driven parts of our industry, has delivered some of the most significant development in modern farming.

For example, technologies to enhance soil and water management, improve sprayer efficiency, minimise environmental impacts or the robotic milking of dairy cows are all being used today by farmers across the globe.

Over the coming years advances in agricultural engineering are key to helping farmers maximise opportunities in order to develop more robust and resilient businesses. It has a major contribution to make to the required advances that will be necessary to deliver more sustainable farming and food. Crop and livestock production systems, will require ever more sophisticated, precision farming approaches.

Deploying new and existing technologies, processes and knowledge that help farming practices to become more sustainable is key. Agricultural engineering will be pivotal to driving forward solutions for greater productivity, profitability and environmental sustainability.

There is no doubt that the world's capacity to produce food in a sustainable way, lies with 'sustainable intensification' – allowing farmers to meet production requirements as well as contributing positively to soil, water and air quality and enhancing biodiversity. LEAF's Integrated Farm Management delivers just this – a whole farm system, balancing the best of modern technology with traditional farming methods.

Caroline Drummond MBE, Chief Executive, LEAF (Linking Environment and Farming) says that with population growth the global demand for food, fibre, and biofuels has to be met with minimal impact on our land, water and biodiversity leaving the food and farming industry increasingly exposed to multiple factors.

Matching future demand and supply sustainably will require precision management of inputs, detection of disease and control of production systems and more efficient use of key resources such as soil, water and air.

Key to this will be continued R&D providing the technology, insights and innovations to help farmers optimise performance, meet productivity requirements, and reduce unwanted environmental impacts, hastened through new ways of working and effective partnerships.

ENGINEERING SOLUTIONS

We need to ensure that engineering solutions are framed effectively at three levels:

- Agriculture needs to overcome biophysical and environmental limits that restrict yields – an area this article looks to address through working for and with nature.
- Expanding and managing farming through more integrated approaches in order to manage and enhance our environment and the associated biodiversity – the foundation of LEAF's work.
- Overcoming the institutional obstacles to the diffusion and adoption of the innovations that could solve these problems – bringing farmers, researchers, educationalists and those in the food chain together to address issues across disciplines.

Delivering the contribution that agricultural engineering must make for scientific advances to reach practice is a significant challenge that needs effective, multi-disciplinary partnerships.

An area where LEAF has been effective in engaging many stakeholders including industry, researchers, government, environmentalists, centres of education, training and innovation to provide the necessary expertise to translate research into practical on-farm application.

Going forward the farming industry and the agricultural engineering business sector need to continue to work more closely with the scientists and innovators to ensure the needs of agriculture, novel engineering and business opportunities are aligned.

Farming will increasingly be required to deliver multiple environmental and production services with the delivery of public goods being key.

Innovations in agricultural engineering are essential to address environmental problems and deliver more sustainable food and farming.

While it is critical to ensure we increase productivity, we also need to be clear on the questions we are looking to answer in order to deliver more sustainable farming.

COMPLEX CHALLENGES

Innovations across a broader spectrum of policies and technologies are needed to confront the complex array of challenges at the agriculture–environment interactions. Supporting farmers to deliver more sustainable farming, through IFM, has been at the heart of LEAF's work for nearly thirty years.

We are in a good position to reflect on our past and progress, further and faster, setting out our plans for more effectively delivering our mission: '***a world that is farming, eating and living sustainability'***.

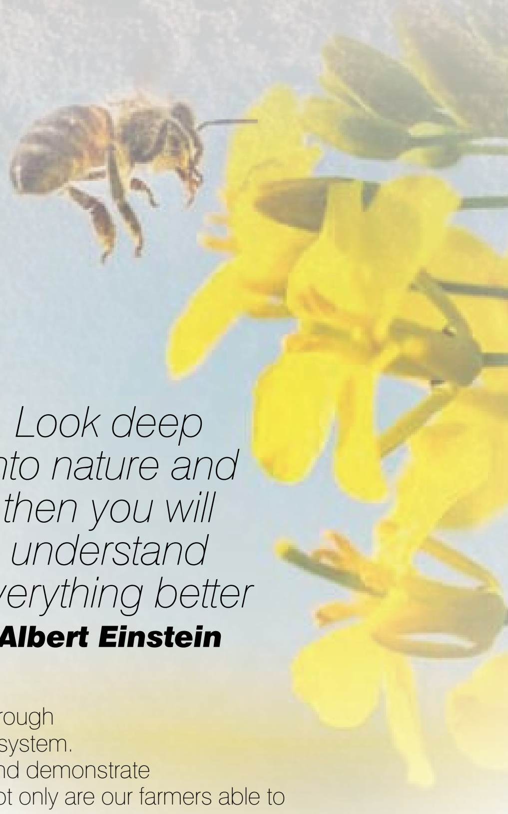
A marked shift is occurring in the way agricultural research is conducted. In particular, there has been a move away from single-factor, mainly on-station research toward active engagement with farmers and farm communities to encourage experimentation and innovation. Agricultural scientists are increasingly observing the principles of sustainability science and engaging with farmers and communities.

We see this through our network of LEAF Demonstration Farmers working alongside our LEAF Innovation Centres.

INNOVATIVE FARMERS

LEAF has been fortunate to be just above the curve of change. With the smart and innovative farmers we work with, we are driving practical solutions for tomorrows challenges.

Where there is positive management we see improvements. Through the increasing uptake of IFM, farmers have learnt the benefits of working with nature to optimise productivity and improve the environment.



Look deep into nature and then you will understand everything better
Albert Einstein

These conservation efforts are further backed up by organisations such as ourselves, in providing guidance and technical support as well as rewarding farmers in the marketplace through the LEAF Marque assurance system. This helps support change and demonstrate impact and improvement. Not only are our farmers able to reap the rewards of a more profitable and more sustainable farming system through IFM but as consumers we can also buy in to the concept through our purchasing decisions.

And nature wins too. Our work is now consistently demonstrating an improved environment and landscape as a result of the adoption of IFM.

What engineering has done for productivity continues to develop at a fast rate from precision farming, the use of drones, artificial intelligence through to developments such as the hands-free hectare. Adaptions of traditional kit in the field to radical re-thinking of cultivations, management of our soil, water and biodiversity are supporting farmers to develop and adapt their practices.

The technology that is developed needs to be supported by effective management decisions and this is where the framework of IFM helps.

NATURE HOLDS ANSWERS

Furthermore, while we look for new approaches to protect, manage and enhance the environment we can also look to nature for new approaches to adopt and develop for our farming.

Natural systems are circular while human-made systems are built linearly. The linear 'take, make, waste' model of our human-made systems, relies on large quantities of easily accessible resources and energy, and is therefore unfit to operate in our increasingly resource scarce world. Improving resource efficiency is not sustainable in the long run, it will not alter the finite nature of resources stocks and often leads to rebound effects (i.e. responses offset the beneficial effects).

Our opportunity is to work with nature.

The future of agriculture depends on biodiversity to select new strains to combat climate change and create genetic diversity, so our livestock and plants can adapt to changing conditions, to improve yields, defend against pests and diseases, build our gene pool and enhance the nutritional benefits of our food.

BIOMIMICRY

For businesses, communities and individuals who seek to find inspiration for new innovative design solutions. Biomimicry offers a great toolkit and helps us to understand natures design principles. This free R&D has evolved over 3.8 billion years.

Not using it to solve some of our most pressing problems, e.g. food security, would be foolish. Most importantly, local contexts matter and thinking in terms of systems, helps in finding leverage points for improvements that benefits the whole value chain. In nature, species that do not adapt to a changing environment go extinct.

With biomimicry, we can develop new products, processes, and systems, or improve existing designs. It can help us to shift our perspective, see design problems and objectives differently, and uncover "new" solutions to difficult problems.

Biomimicry is unique among other bio-inspired design approaches in its emphasis on learning from the capacity of living systems to arrive at sustainable solutions to specific functional challenges.

Such examples include the development of windturbines based on the humpback whale which has scalloped edges on its flippers which reduces drag in the water by 32 %, the development of concrete that sequesters CO2, and learning from some of the wonders of nature such as the capability of the Amazon electric eel capable of emitting 860 volts of electricity, our own blood cells that filter salts out of water, the capillary action of trees, the ability of gecko foot pads to create adhesion without adhesives.

So many solutions all around us every day. Being flexible, vigilant and adapting to our increasingly resource scarce world is a win-win situation for people and planet.

UK AGRICULTURAL ENGINEERING DELIVERING CHANGE

Our food production system is underpinned by agricultural engineering. Its importance to the future is fundamental. It contributes to the provision of a range of non-food services including equipment and systems for conserving natural resources, controlling pollution, enabling the management of natural capital and mitigating the impact of weather and climatic events.

The farming sector does face complex problems: continuing demand for food, volatility in global food prices, global hunger and the impact of climate change on farmers ability to enhance the environment and deliver a range of vital ecosystem services.

The concept of sustainable intensification – maximising food production efficiency whilst reducing environmental impacts will require innovative technologies to help farmers optimise performance.

Crop selection and management, precision livestock farming, sustainable soil and water management, pest and disease control, food safety, quality and traceability are just some areas where advances are being made.

The opportunities for engineering solutions to advance more sustainable farming and food production are limitless.

What has been achieved through the development of agricultural engineering in our crops and livestock management, water and wastewater technology, energy, reduced soil degradation, etc, needs to be further developed in managing our precisions natural resources and biodiversity. Sometimes, all we have to do to solve complex design problems is look to nature. we can all learn a thing or two from the natural 'lab' that surrounds us.

The opportunities are there, but if the farming industry does not take them up then the added value opportunities will be lost to others, including the importers.

Finding practical, realistic and achievable solutions is at the heart of how LEAF contributes to promote positive change in food and farming and its contribution to the environment and health, and we look forward to seeing you at Cereals to work with us to be a part of a drive to deliver more sustainable food and farming.

Ensuring Healthy Food and Farming – Fit for the Future. Together we can all make a difference.

LEAF (Linking Environment and Farming) develops and promotes Integrated Farm Management through the setting up of demonstration farms and management tools for farmers. A leading environmental and farming charity LEAF encourages the progression of sustainable farming techniques and a better public engagement and understanding of farming practices. LEAF runs Open Farm Sunday and is actively involved in education and inspiring the next generation of further farmers and those in the industry. www.leafuk.org

Meet a Member

HELEN DAVIES CEnv MIAgrE

Helen Davies is the first member of the Land Drainage Association to achieve Chartered Environmentalist status through IAgrE and works for a leading civil engineering company.

I have 11 years' experience of Programme and Project Management in local government and an extensive background in agriculture and rural development in both the private and public sector, including 12 years beef and sheep farming in Mid Wales.

My initial interest came from working in the agricultural pharmaceutical industry in the 1980's advising farmers on safe sheep dipping practice. At that point I realised no matter what industry I worked in there would be environmental impacts to reduce and opportunities to improve sustainable development

I wanted to achieve professional registration as a Chartered Environmentalist because I felt the recognition gained would help me make a more positive impact across the wider industry. Membership of the Institution of Agricultural Engineers has given me access to information on new industry technology and innovation along with invaluable help and support.

I think my most rewarding career achievement was achieving an MSc, whilst working full time and bringing up 2 children.

I now work freelance as an environmental and waste management consultant with small Civil Engineering, haulage and plant hire companies in North Wales. What I love about my job is given the nature and range of the works, no two days are ever the same and there are always new and exciting challenges to face. The companies I work with are all wholly committed to sound environmental and waste management and ensuring sustainable development for the future. However, getting individuals to understand their responsibility and commitment to these aims and make them part of their 'day job' remains a considerable challenge.

I have always believed that to have an enjoyable and successful career you should choose one that either involves a hobby or topic you have a deep interest in.

Away from work, I look after a former derelict farm yard which my husband and I converted into a home and 2 holiday cottages, which recently achieved a prestigious environmental award.

CROP SPRAYERS

The Silsoe Spray Application Unit (SSAU) is an internationally recognised facility for research, development and bespoke testing of sprays and sprayer technology particularly in the application of agricultural pesticides. **Professor Paul Miller** FREng CEng CEnv HonFIAgrE and **Dr Clare Butler Ellis** CEnv FIAgrE from the SSAU chart the development and use of plant protection pesticides and likely future trends

At the time when the Institution of Agricultural Engineers was formed, 80 years ago, the use of plant protection chemicals did not figure largely in any part of agricultural production anywhere in the world.

In 1960, the global market for plant protection products was less than one billion dollars but by 2011 this had risen to almost 50 billion dollars with herbicides accounting for the largest market share worldwide. For arable crops in the UK, surveys show that the quantity of pesticides is still increasing with more than 16.5 thousand tonnes applied in 2016 – an increase of approximately 2 thousand tonnes since 2010.

The equipment for applying such plant protection chemicals has also changed substantially since the 1960's although machines continue to comprise the main components of a tank, a pump, a control system and some nozzles on a supporting boom.

This article highlights just some of the key developments relating to arable crop boom sprayers that have occurred over the last 80 years - some of which will also be relevant to sprayers used to treat bush and tree crops and other horticultural crops in a wide range of environments.

BIGGER, FASTER, LESS WATER

One of the most important factors influencing the efficacy of plant protection products is the timeliness of application and this in turn is linked to work rate. For boom sprayers operating over field crops, higher work rates are mainly achieved by having wider booms, faster spraying speeds and applying less water.

In the 1960's, a typical arable farm sprayer might well have been tractor-mounted (although some trailed machines were used), have a tank size of up to 1000 litres capacity and a boom width of up to 12m that would be rigidly attached to the sprayer frame. Such machines would typically operate at speeds of 4 to 8 km/h to apply 200 l/ha of spray liquid. Machines going on to larger arable farms today are likely to be self-propelled or trailed, have boom sizes of up to 36m with passive and/or active suspension systems, tank sizes of up to 6000 litres and capable of operating at 16 km/h and more.

Such machines involve high levels of engineering design, manufacture and testing inputs not only in relation to the spraying components, but also the support vehicle and its associated systems. As well as improving timeless, higher work rates enable larger areas to be treated hence spreading the capital cost of the machine over more hectares.

TANKS AND FILLING SYSTEMS

A modern sprayer will have a tank made of a material that is chemically inert, has a smooth surface inside and out for easy cleaning, drains to give a very small residual volume and is shaped so that the contents can be effectively agitated.

When sprayers were relatively small, they could be filled with water from a hose connected to the mains or a bowser and with chemical poured into the top of the tank. As sprayers became larger, climbing to the top of a tank carrying concentrated formulations posed substantial environmental and health and safety risks.

Low level filling stations were therefore developed based on induction hoppers that enabled large sprayers to be filled with chemical formulations with the operator standing on the ground. Induction hoppers commonly use a Venturi valve in the bottom of a small hopper to draw formulations into the sprayer together with a wash down flow of water directed at the side walls of the hopper to ensure that all material poured into the hopper gets rinsed away from the side walls. An arrangement for rinsing containers is usually included based on a specialised nozzle that directs rinse water under

pressure into empty containers.

While the development of induction hoppers substantially reduced the risk of operator and environmental contamination with neat formulations, pouring such formulations into a hopper still poses some risk.

Closed transfer systems have therefore been developed that allow a container to be connected to the sprayer via a specialised filling system that does not expose the concentrated chemical to the atmosphere and gives low levels of residue during the connection to and disconnection from the chemical containers.

NOZZLES AND SPRAY GENERATION DEVICES

Conventional flat fan nozzles have been used on boom sprayers since such machines were first developed. In the early days, machines used nozzles formed in brass or plastic with a limited choice of specification and there were real concerns about nozzle wear and the effects of the chemical on the nozzles.

The development of engineering plastics with good abrasion resistance, the use of high grade stainless steel and ceramic materials has meant that nozzle systems are now more robust although calibration and maintenance are still important. The performance of agricultural spray generators (nozzles) is defined in terms of the following parameters.

- Flow rate – the range from 0.4 to 6.0 litre/min used for agricultural applications is now divided into some 12 sizes each based on a nominal value and colour coded so that it is easy to check nozzles along a boom (although detailed inspection is still needed to check that the nozzle types are consistent). Once on a machine, adjustment to the flow rate is generally made by changing pressure but the square root relationship between pressure and flow through an orifice means that, for example, a doubling of flow would require the pressure to be increased by a factor of four. For this reason, the range of flows that can be achieved by conventional hydraulic pressure nozzles is limited to some +/- 25% of the nominal value (a turn-down ratio of 1.25:1). Extended range/variable pressure nozzles have now been developed that increase this range by changes to the output orifice to give turn-down ratios of around 1.4:1 and other nozzle designs such as the twin-fluid nozzle that uses compressed air as well as pressurised liquid have sought to address this limitation.
- Droplet size distribution – most conventional and related nozzle designs produce a range of droplet sizes which can now be measured in-flight with laser-based instrumentation. The droplet size distribution is expressed as a spray quality (very fine through to very coarse) based on the performance of defined reference nozzles. Much work, particularly in the 1960's and 70's was directed at generating sprays with a closely controlled droplet size mainly by using spinning discs, but such systems have not been widely exploited on boom sprayers.
- Liquid distribution pattern – the "footprint" of the spray from an array of nozzles mounted on a boom with the specified spacing and operated at the correct height. Results from such measurements are used as a measure of nozzle quality.
- Spray fan angle and droplet trajectories – most sprayers now use nozzles with a spray fan angle of 110 operating with a nominal boom height of 500 mm – 80° nozzles can be used at greater boom heights. Designs are now available that angle the spray in the direction of travel aimed at increasing deposition on small vertical targets such as grass weeds. In the 1970s and 80s it was thought that electrostatically charging the spray would lead to substantially increased target deposition and demonstrations treating single plants were dramatic. Different charging systems were brought to the market but the performance in field crops did not deliver the anticipated benefits.
- Drift risk – over the last two decades there has been increasing attention to the need to control spray drift. Both field and wind tunnel tests have been defined for assessing the drift risk from sprayers based on comparisons with a reference configuration and, in the UK, LERAP star ratings are now used as a basis for modifying the width of buffer zones at the edge of fields. Much research and commercial development has been aimed at drift reducing nozzles and it is now estimated that air-induction designs account for more than 50% of

boom sprayer applications. Air-induction nozzles use a pre-orifice and Venturi effect to draw air into the nozzle body and a relatively large final orifice to deliver a spray that has air bubbles within the droplets. The droplets are substantially bigger than those from conventional nozzles operating at comparable flow rates such that drift reductions of more than 75% can be achieved – a LERAP three-star rating.

Spray operators now have a wide choice of nozzle types and design that can be used to give high levels of target deposition, product efficacy and environmental safety.

CONTROL SYSTEMS

The controllers on the early crop sprayers aimed at providing an on/off switch for different sections of the boom and maintaining a pre-set pressure at the nozzle. It was then important to drive at a constant speed to get uniform application.

The next development stage aimed at keeping application rates constant over a range of spraying speeds by adjusting pressure at the nozzle using speed sensors and monitoring nozzle pressure or flow. However, the turn-down ratio that can be achieved with pressure nozzles (1.4:1 for extended range/variable pressure designs) limit the speed range over which such systems can operate and provide no options for spatially variable applications based on mapped and/or sensed parameters. Control strategies have therefore been sought that, as an alternative to the use of twin-fluid nozzles or spinning discs, enable higher turn-down ratios to be achieved. These include:

- Multiple nozzle holders at each nozzle position along the boom such that different nozzle sizes (and types) can be switched depending on demand from the control system;
- Pulse Width Modulated systems (PWM) whereby the output from a nozzle is pulsed at relatively high frequency using a valve arrangement very close to the output orifice (tip) and the proportion of the valve open time is adjusted to change flow rates.

Most modern crop sprayers now use control systems that are computer-based and some now use CAN networks on the boom such that functions at each nozzle station can be controlled independently – switching individual nozzles on/off in its simplest form but with more complex functionality where multiple nozzle holders are used.

Most have links to satellite-based in-field location and the ability to both map and respond to mapped instructions such that it is possible to patch spray parts of a field with different dose levels applied to defined field areas.

Direct injection systems where the neat chemical formulations are carried separately on the sprayer and only used when required would enable patches to be treated with different chemicals but, to date, the technical problems associated with engineering practical injection systems have limited the commercial introduction and acceptance of such systems.

Commercial machines have now been launched that identify individual weeds growing in row crops based on computer image analysis examining weed size, position and colour and then directing a spray only at the detected weed. Such machines require nozzles that can be actuated very quickly (typical off/on/off cycle times of less than 0.05 seconds), have a very sharp-edged footprint and do not generate small droplets that might drift from the identified target.

Field trials with prototype machines showed the potential for large reductions in herbicide use (more than 95% reductions compared with overall spraying) and levels of control and crop damage that were competitive with all other control options.

FUTURE DEVELOPMENTS

As the use of pesticides continues to be under pressure from both regulations and a negative public perception, significant efforts to develop alternatives to chemical controls are being made. Integrated Pest Management, which is mandatory under the European sustainable use regulation, should encourage movement towards combining all these alternative techniques so that conventional chemicals are the last resort and used in the lowest possible quantities.

But they will remain a key part of protecting crops for both yield and quality for the foreseeable future and we are unlikely to see crop sprayers disappearing from our fields.

There is little evidence that the trend towards larger machines has reached its peak although many people now think that further increases in machine size are unlikely given the problems of soil compaction and transport on the road network.

Timeliness of treatment will continue to be a major plank in any strategy aimed at minimised plant protection product use and so high work rates will have to be maintained. If machines do not get wider, then there will be continued pressure to operate at increased spraying speeds and with reduced water volumes.

The need for timely applications mitigates against the use of small autonomous robots for arable field spraying although such approaches will probably have a role in small scale, high value crop situations. The most likely form of 'robot' crop spraying in arable fields will be with a conventional machine in which crops and the environment are sensed, spray is targeted accordingly, drift is controlled, the regulations are met, records are kept, the sprayer is powered and steered automatically while the operator is probably still in the cab making sure that all is well, and able to override if not.

This is a reality that is not far away, and we can expect to see much more decision-making and control by the on-board computer in the next few years.

The potential for improved targeting of spray applications based on patch and spot applications is likely to continue to be developed but further incentives are needed if such approaches are to be adopted rapidly.

We also need encouragement from the regulations - perhaps by accepting that the 'dose' for which risk assessments are carried out relates to the average over a field, rather than the maximum quantity applied to a small area. Existing pesticides could then be used much more effectively at the same time as reducing average doses.

Meet a Member

SAM MOULDING EngTech MIAgrE

Sam is a technician and workshop supervisor on a farm, part of the G's Growers Co-Operative, one of Europe's largest salad and vegetable growers.

When I told one of my school teachers I was going into this industry, their response was "Why would you do that, it's a dead-end job with no chance of progression." How wrong could they have been! I know of no other industry that could provide so much knowledge and training on a range of skills.

I took a four year apprenticeship at Easton college (now Easton and Otley), during which time I could work, learn (and more importantly for a 16 year old lad earn) as much as I wanted.

The variety of work that comes through the farm is immense and there has never been a chance to get bored in the fifteen years I have been doing this job.

Three years ago the opportunity to become a workshop supervisor came up. I took on this supervisory role in which we have a team of eight engineers and a contractor.

Our workshop has always worked on the theory that nothing is impossible. This has seen us designing and making machinery for the farm to use, as well as servicing and maintaining the farm's vast array of machinery.

For anyone who is prepared to put the time and effort in, this is the most technical varied and rewarding job around.

Of course, some days when you're stuck outside in the rain and mud, you can ask 'what am I doing here'? But the good days more than make up for all that.

As a farm rather than a main machinery dealership, we don't enjoy some of the training opportunities, but I have been to Germany for training on the machinery we operate, along with others for health and safety.

If I had to sum up this industry in three words they would be Innovative, Rewarding and Challenging.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THE DAIRY FARM

Jim Brook IEng MIAgrE is Commercial Product Specialist at Lely Atlantic Ltd. Previously, he spent almost 40 years at DeLaval Ltd in a variety of roles in the UK, Sweden, Saudi Arabia and China. A Council Member of the Milking Equipment Association (MEA), he examines the traditions and evolution of dairy industry over the past 80 years

I could never have imagined that when I left school in 1975 to work as an apprentice for a milking machine manufacturer, that now 43 years on I would still be working in the very same Dairy Farming industry.

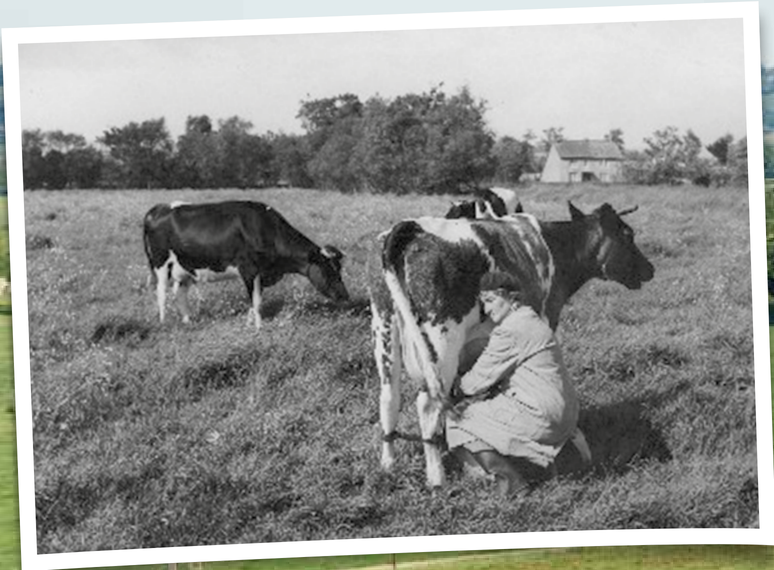
This means that I have been associated with the industry for more than half the time that the IAgrE has been in existence! So here I am, still here and still involved! I expect I am not any different to most Dairy Farmers and colleagues in this industry, who revel in the challenges it brings.

My mother came from a farming background, her parents were tenanting a farm on Lord Halifax's estate near Leeds. She remembers during the 40s and early 50s delivering (raw) milk from the family farm, ladling it out of a churn into the customer supplied vessel.

Delivery was initially from the back of a horse and cart, latterly from a van to the local unsuspecting population. Unfortunately, the milk round ceased when compulsory TB and brucellosis testing came along in the 50s, requiring milk for sale to the public to be pasteurised, and all standing areas used for milking had to be concreted, which was deemed too costly. This was at a time when 70% of cows in the UK were still being milked by hand.

Early attempts at milking cows involved a variety of methods. Around 380 B.C. Egyptians, along with traditional milking-by-hand, inserted wheat straws into cows' teats. There are even earlier records of Central Europeans milking by hand, as found on cave artwork.

Suction was first used as a basis for the mechanised



harvesting of milk in about 1851, although the attempts were not altogether successful. To encourage further innovations, the Royal Agricultural Society of England offered money for a safe, working milking machine.

Around the 1890s Alexander Shiels of Glasgow, Scotland, developed pulsation that alternated suction levels to successfully massage the blood and fluids out of the teat for proper blood circulation.

That device, along with the development of a double-chambered teat cup in 1892, led to milking machines replacing hand milking.

During the 1920s, machine milking became firmly established in the Dairy industry. Into the 1940s and there was now a well-developed machine milking system, with a much better understanding of the interaction between cow and machine. The teat cup, liner, milking and pulsation vacuums were all technically reliable.

It was and is in fact, animal genetics that drives the development of the milking machine as much as technological development. Today, the majority of all milking is by machine.

MILK STANDS

The modern history for the UK Dairy Farming sector began in 1933. Up until then Dairy Farms were many and small, their product a perishable liquid, heavy and difficult to transport.

The UK government's solution was to set up producer marketing organisations. Their aim was to preserve and increase farm incomes and to protect them from the inherent economic weakness of agriculture - a huge number of small producers selling a bulk commodity to a small number of buyers. It was at that time that milk became a part of the staple diet in the UK, largely due to the wider sale of safe to drink pasteurised milk.

As many as 150,000 farmers produced milk of varying quality, and it was also around this time that The Milk Marketing Board (MMB) was established, to standardise the way farmers were compensated for milk, focusing mainly on volume rather than quality.

Do you remember the 'milk stand' that stood outside the farm gate, many of which still remain? The milk was collected from the milk stand, a sort of bench that was the same height as the lorry bed, in churns of 10 or 11 gallons, weighing in at over 100lbs.

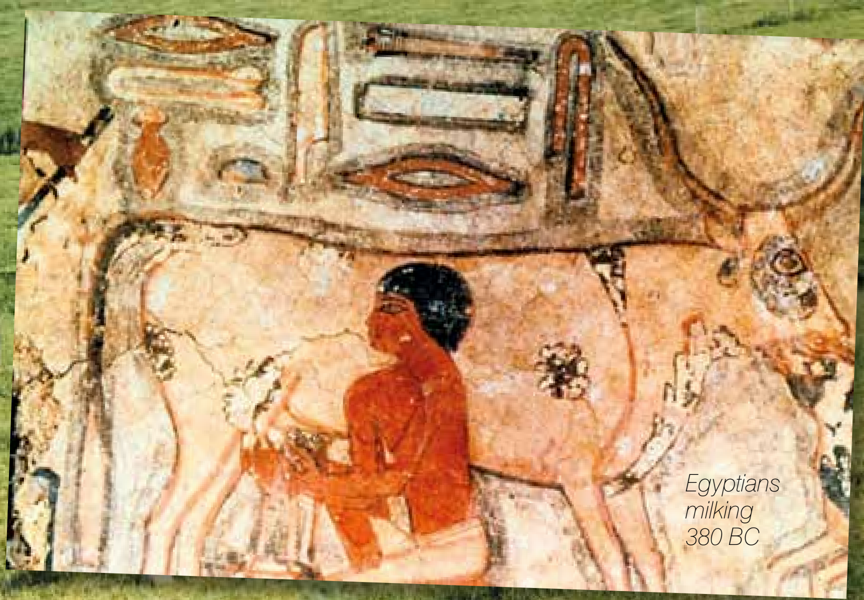
Quite some job for the driver collecting hundreds of churns every day. I remember in the summer months you quite often saw red labels tied to the churns as the milk was rejected for being too warm or it had gone off. Not surprising when often the cooling method was 'cold' water from the tap running down the sides of the churn!

It wasn't long before, in the 60s and 70s, refrigerated bulk milk tanks replaced churns as the preferred method of storage

The MMB successfully managed the supply of milk for over 60 years, until it was disbanded in the early 1990s only to be replaced by Milk Marque. Both were seen as anti-competitive monopolies which didn't fit with the ideology of the 90s so they were abolished due to anti-competition and monopoly regulations!

A free market was then introduced to encourage competition and increase efficiency. Once quotas were removed in 2004 the production potential of European dairying took off.

For those 60 years the milk boards provided a reliable service. Tankers arrived daily to collect the milk then the milk cheque arrived promptly every month. To some extent farmers traded short term profit opportunities for long term stability and it worked well.



Egyptians milking 380 BC


Early milking bail

Dairying prospered under the aegis of the MMB's. In the 1970's milk price was rarely mentioned and grants were freely available. Many machines and buildings subsidised by the FHDS grant scheme still exist even to this day.

In the 80's production per cow had more than doubled in 30 years however the EU had a surplus to deal with, counteracting this with intervention buying until the ocean of milk became too large. Milk quotas were then introduced in 1984 based on historical milk sales.

At this time, many decided to give up milk production as it was not a financially secure option in many cases.

Many milking machine manufacturers also ceased trading around this time. Some of those who stayed in Dairy Farming decided to add value by dealing with the consumer directly as producer retailers or by making cheese and ice cream.

The varying cultural and ethnic revolution in our population has to some extent driven this entrepreneurial spirit, with many types of yoghurt and other products now available, including low fat and organic.

MILKING BAILS

I mentioned earlier that there were about 150,000 Dairy Farms in The UK in the 1930's and with still as many as 120,000 when I joined the industry in 1975.

Currently there are about 13,000 Dairy farmers, including Scotland and NI. (I often wonder if the decreasing numbers has anything to do with me!).

Cow numbers have remained fairly stable over recent years at just under 2m, but herd average size in cow numbers has risen to more than 130 animals, with production averaging around 8000kg per cow.

Most Dairy Farms are now situated around the M4, M5, M6 corridor, adjacent to the larger populated conurbations. South and North Wales boast hotspots, and in Scotland, the South West is also a dominant milk producing area. The Dairy manufacturing companies generally have adopted these areas for milk processing factories.

Perhaps one of the earliest innovations seen in the development of the Dairy Farm was not the machine itself, but a breakthrough concept. Milking bails became popular on the level fields of Somerset, Dorset and Wiltshire.

This concept took the machine to the cow in the field, as opposed to the cow coming to the machine. Interestingly, this idea has been re-visited with the advent of robotic milking, where terms such as 'Cow Comfort', 'Organic', and 'Grazing' are trending. The idea for the milking parlour was born out of the bail milking concept.

Remembering now, when there was a Milking Machine Avenue at The Royal Show in July and The Dairy Event in September, hosted at the showground in Stoneleigh.

Long gone milking machine manufacturer names such as Manus, Simplex, Weycroft-Macford, Gascoigne Gush and Dent, Hunday, Hosier, Freddie Browns Bails and Tractorvac (yes, a milking machine driven by the air inlet of a tractor's engine!) were all there to sell their wares.

It is mostly the companies that spread the risk that have survived. Delving into export markets, consumable and After Market sales and specialised systems.

Even now, the plethora of designs of milking machine to choose from still amazes me. Some have been and gone, but still the variations are mind boggling. Fast Exit, Tandem, Rotary, Robot Rotary, Round The Shed (RTS), Bucket, Abreast, Herringbone, Parallel and of course the future of the Dairy Farm, Robots, automation and smart management.

AUTOMATION

The first automated systems such as cow identification, automated feeding and milk recording first popped up in the


Early automated machine at Silsoe

late 1970's. Since then, electronics and automation have developed beyond our wildest dreams.

Whilst speaking of robots, let us take a peek into the future - The fully robotic farm.

Adoption of automation is really gaining pace now, there seems no stopping to this trend. The vision is fully robotic Dairy Farms worldwide. Robotisation is in most countries, the only answer to labour shortages. Fewer people want to work in the agriculture industry, and automation offers a real solution.

- A fully robotic farm has the milking robot at its heart, and runs fulltime, 24 hours a day.
- Because most processes are automated, the farmer can pay attention to those individual cows that really need attention based on available cow specific data and information. This helps the herd, but also the farmer who develops an improvement mindset versus a firefighting mindset!
- The fully automated, decision based farm management system assists the farmer in his complex decision making process. Besides data generated by the milking robot, he also uses data from feed suppliers, veterinarians, weather forecasters, insemination suppliers etc.
- The system will be self-learning and over time adapt to the farmer's preferences for running the farm. The system proposes or even takes decisions, which will lead to increased profitability, sustainability and enjoyment for both farmer and cow.
- The farmer can predict and plan robot maintenance, using remote support and all available data sources. In most cases he can solve problems himself or with the online help of his local dealer. If needed, the technician is quickly on the scene to solve the problem, sometimes making use of virtual or augmented reality. In many situations, 3-D printing of spare parts which could even be done at the location of the farmer, in the back of the service van.


Lely Astronaut Automated milking machine

It is fair to say that within the Dairy industry, although many see it as disparate, we have had everything thrown at us. And the challenges we continue to face are many. Regulation, deregulation and re-regulation, Quotas, diseases such as Johnes, TB, Foot and Mouth disease (three times), Mad Cow/BSE not to mention lameness and mastitis are all matters of concern and considerable cost to both man and animal.

As we move into the next phase of the Dairy industry, we continue to see new entrants. Farmers, manufacturers and dealers alike take on the challenge. Tough times will come and go, but Dairy Farming for sure is here to stay.

Try to name any other industry where machine and animal are linked so closely together, working in perfect harmony.

I acknowledge the following sources for this article:
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www.ahdb.org.uk/marketinformation- data/producer-numbers/
www.madehow.com
www.lely.com

Engineering in Turfcare Machinery.

The design and engineering principles employed by Edwin Budding when he invented the worlds first lawnmower in 1832 may not have changed, but todays grass cutting machine owes much to new technology says **Ian Sumpter EngTech MIAgrE** who was Training Manager for The Toro Company in EMEA and now owns and runs Mow-Sure Training Ltd

GRASSCARE AND AMENITY

'Not much has changed over the years since Edwin Budding's design, first brought cylinder technology to the turfcare industry'.

I often hear this statement and have said it myself from time to time when speaking at seminars internationally. But is the statement correct and is it correct for the turfcare industry to continue to think nothing has changed? If not, what engineering changes have we seen since Edwin Buddings original engineering designs?

From a pure engineering prospective, I agree the process of a cylinder rotating and cutting turf has not changed and for that we owe Edwin Budding high praise as an engineer. Edwin Beard Budding was a British engineer from Eastington, Stroud, he is renowned as the English inventor of the lawnmower in 1830. In true British engineering he had the idea after seeing a machine in a local cloth mill which used a cutting cylinder (or bladed reel) mounted on a bench to trim cloth to make a smooth finish after weaving.

Up until that point the scythe was the only option for cutting grass, so Budding's mower design was primarily to cut the grass on sports grounds and extensive gardens, as a superior alternative to the scythe, and was granted a British patent on August 31, 1830.

As a side note, unbeknown to a lot of people Edwin Budding later went on to invent the adjustable spanner in 1842 – and I will leave the pros and cons of adjustable spanners open to debate . . .

So can we rightly say from an engineering point nothing has changed since that first British design mower? On the same thinking we could say nothing has changed with the automotive industry since Henry Ford first introduced the model T production line. Or nothing has changed with flight design since the Wright brothers first took to the sky's. Ok not quite, but you get the idea. If we all thought this, I guess this would be where my article ends.

As engineers we know there has been a huge advancement in engineering in the automotive and aircraft industry. At some point the generic technology being developed finds its way through to the turfcare industry, and mixing with specific industry engineering creates our own advancement in technology.

As an operator or technician of mowing equipment since the early eighties, I often ask myself whether I have noticed huge changes? From a mowing perspective, I get on a machine, engage units and cut grass, so I would say; I have noticed very little difference over my 30 years.

Looking behind the scenes, which I have been privileged to do for 15 years of my career, working with a major turfcare manufacturer I can give a completely different answer.

In brief the engineering principle of turfcare equipment, in its raw form has not changed. The way we apply that engineering principle has been morphing into what we see in modern mowers today.

I remember the time when we cut golf greens at around 6mm in the winter and 4mm in the summer. In recent years due in part to new fine turf grass species, customer demands and changing climate we have seen machinery having to achieve lower heights of cut throughout the year. In some cases golf greens are down to as low as 2mm.

ENGINEERING INITIATIVES

To meet these demands manufacturers turned to engineers to look for a mechanical solution that can achieve a consistent height of cut as low as 2mm. At the same time as being able to cut down to low heights of cut the mower needed to work on a growing, living, undulated surface taking into account multiple variables.

To cope with any slight undulation the cutting unit needed to be engineered as a floating head and a new design thinner bottom blade strong enough to cope with the task. This engineering solution required engineers that are resourceful, flexible and with industry knowledge to find the answers. The solution resulted in a completely redesigned hand mower that could cut down to 1.8mm.

We have seen a number of engineering initiatives to the set-up process, bottom blade to reel adjustment and height of cut adjustment has been changing over the years. Engineers have been developing processes to make

adjustments easier and maintain quality of cut longer.

We have seen quick adjustment designs that make adjusting heights of cut a fast operation by using a power drill. With this method engineers designed the unit with a spring-loaded rod that ties both ends of the roller together, so you can perfectly adjust both sides of the reel from one side.

A worm gear translates multiple revolutions into precise increments, so a power drill can be used in place of physically turning a spanner. The worm-gear also locks in the height-of-cut, so it can't shake loose.

Another innovation has been a magnetic bottom blade making changing bottom blades easy. This engineering solution allows knives to be easily and regularly swapped for topdressing applications or to accommodate changing conditions. It's a solution that can save time – instead of unscrewing, removing and torqueing knives back into position, the knife can be popped off for maintenance, perfectly aligned and replaced.

The type of metals being used today varies, tungsten steel and particularly strong regional steel to improve the life and quality of units. To improve on current cutting units engineers have modified geometry to improve blade twist. Changing the bedknife top angle resulted in a smaller land area between the reel and bedknife and changed the reel blade rake angle.

DIAGNOSTICS

Electrical engineering using electronic control (ECUs) units have made the electrical systems simpler, removing relays and reducing electrical wiring and components. We see modern mowers utilising drive by wire as the traction control can be adjusted by sending an input signal to the ECU which sends an output to the fuel governor controlling the engine speed.

These ECU's have allowed mowers to have diagnostic capabilities and helped reduce mechanical linkage and hydraulic components.

Technicians still require the fundamentals of engineering but with all these changes we have seen the need for a different technical skill set than in the past. We now see diagnostics requiring the ability to utilise laptops and slightly different thought process to troubleshoot issues.

Newer more capable electrics have more advanced diagnostic capabilities than ever before and when fully understood through training, give customers more capability to fix faults without the need to plug in diagnostic tools.

In the future, using information technology and wireless systems the diagnostic capability on mowers will extend into reporting systems where a machinery manager will be able to have this information show on his phone or palm computer.

He will be able to know what error code is on the machine and plan accordingly.

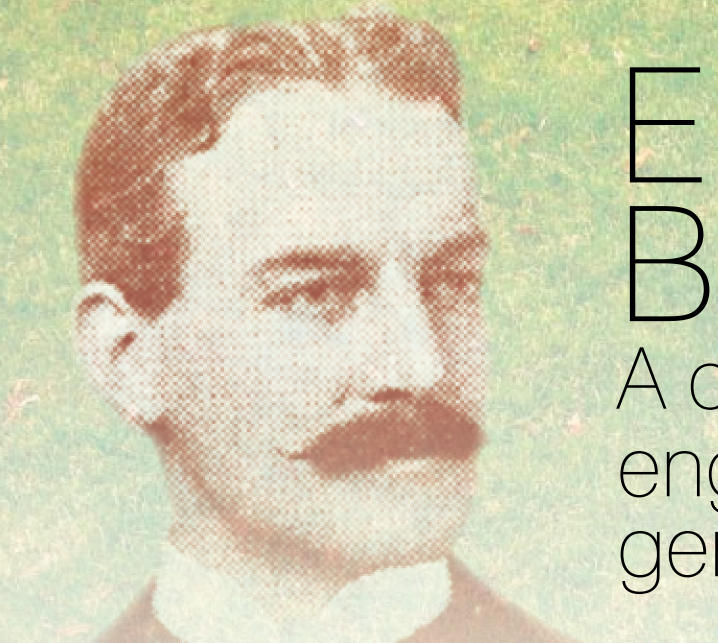
We are seeing agricultural engineering filter into turfcare sprayer control systems that allow for more precise application by using satellite positioning and RTK bringing the accuracy within a few centimetres. Using information technology and wireless systems this capability on sprayers will extend into IT reporting systems.

A course manager will be able to have this information show up on his computer. He will know precisely what has been applied, where and what rate.

With the automotive industries drive towards hybrid and electric powered vehicles we have seen a similar move within the turfcare industry.

Engineers are developing electrically powered mowers capable of working in commercial environments. As well as smaller engines that coupled with battery technology and onboard generators can produce the horse power requirements for today's larger areas such as fairways.

Every aspect of the modern turfcare industry is being influenced by engineers whether it is re-engineered solutions currently available from other industries or new engineering solutions.



EDWIN BUDDING:

A complex engineering genius

Edwin Budding was born in 1796, the illegitimate son of a farmer. In the 1820s he worked as an engineer and machinist at the Phoenix Iron Works at Thrupp near Stroud - a former mill that local businessman John Ferrabee had leased and subsequently gained permission to convert to an engineering works manufacturing machines for the cloth trade, water wheels, steam engines and farm machinery.

In 1815, John Lewis, son of the owner of Brimscombe Mill which adjoined Thrupp Mill, invented a new-style napping machine employing a horizontal blade that could be rolled across the surface of the cloth.

In 1830, Budding stumbled across a method of cutting grass mechanically, a task that was hitherto undertaken by scythe. On 18th May of the same year, he signed a formal Agreement with Ferrabee acknowledging that he, Edwin Beard Budding *"had invented and applied a new combination for the purpose of cropping and shearing the vegetable surface of Lawns, Grass Plots and Pleasure Grounds, constituting a machine which may be used with advantage instead of a sithe (sic) for that purpose"*.

Buddings 'eureka' moment for a machine to mechanically shear grass had come whilst he was involved in engineering a machine that would shear off the rough nap on the cloth used for guardsmans uniforms so they had a smooth finish.

A few months later Budding and Ferrabee applied for, and were granted, a patent which described the invention in minute detail including specifications of the drive wheels, pinions, gears, cogs, cutting cylinder and so on.

His invention came at an opportune time. Across the country, manual tasks were being replaced by machines. But it was also a time of growing leisure time as a result of greater mechanisation. Sports and pastimes like cricket, golf and tennis were becoming more popular. In London, Thomas Lord had already founded the famous cricket ground that carries his name.

Adjoining the Phoenix Iron Works were a number of meadows. It is entirely possible that these were tended by a scythe, and that Budding had noted that the grass was only being cut during wet weather or at a dewy dawn.

His machine was different. It could be used when the grass was dry and the sun was at its highest. For two or three years, Budding and Ferrabee perfected their invention, often testing prototypes in the dead of night, just in case they be laughed at or possibly to stop others stealing a march on them.

The time-scale from prototype to marketable machine was extraordinarily swift. Within two years (1832), Budding and Ferrabee had signed a manufacturing licence with the agricultural engineering company Ransomes who were looking to diversify from farm machinery.

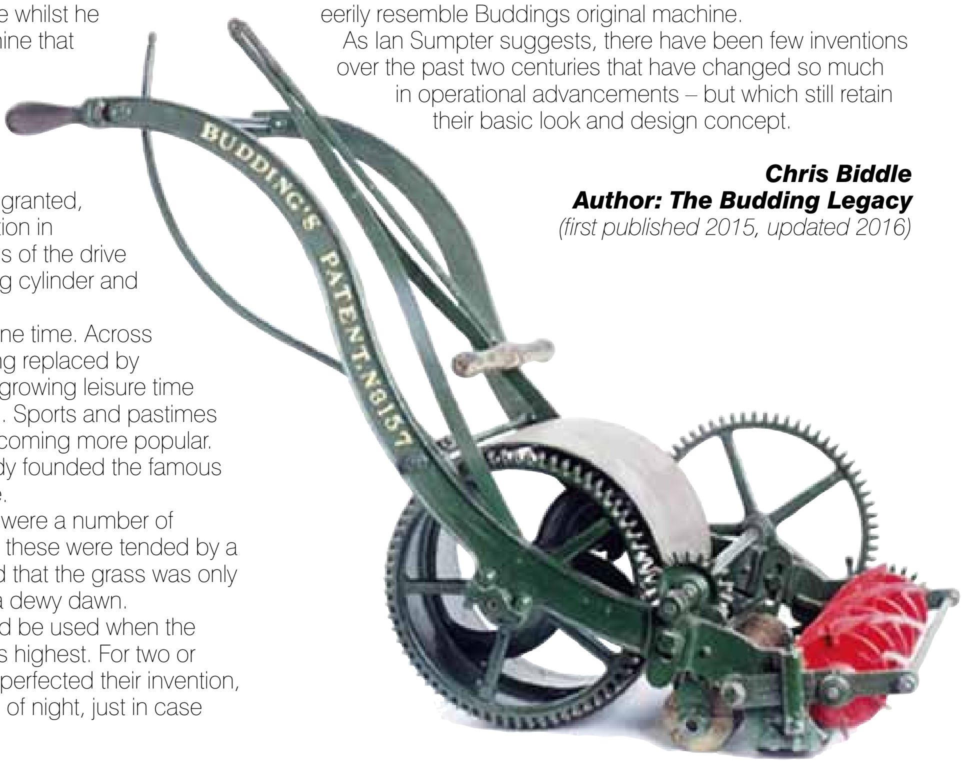
There followed a number of other manufacturing licences for Budding's invention. His relationship cooled with Ferrabee, and he moved the short distance to Dursley where he teamed up with George Lister, son of the founder of R A Lister to develop new carding machines for the textile industry.

Thereafter, Budding lived a quiet life in a modest cottage until his death at the age of 50.

Much is made of the engineering acumen of Edwin Budding, his technical skill and innovative mind. What is often overlooked is the design itself, the aesthetic look that has lasted a lifetime.

Search in garden sheds up and down the land, and you will find thousands of mowers from more modern times that eerily resemble Buddings original machine.

As Ian Sumpter suggests, there have been few inventions over the past two centuries that have changed so much in operational advancements – but which still retain their basic look and design concept.



Chris Biddle
Author: The Budding Legacy
(first published 2015, updated 2016)

CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

As a professional society, IAgrE is commited to providing a wide range of Continuing Professional Development (CPD) events. Members registered with the Engineering Council and Society for the Environment are required to maintain CPD records and IAgrE conducts an annual sample of those records.

WHAT DOES THIS MEAN IN PRACTICE?

Steve Copnall IEng MIAgrE is Product Specialist at Turfmech Machinery. His responsibilities include designing and implementing product test programmes to replicate product life and working conditions, improving manufacturing quality and processes where necessary.

"Being technically minded, I enjoy problem solving and developing new methods to improve product quality and learning new technologies" he says.

Steve gained HNC Building Studies, HNC Mechanical Engineering and ONC Mechanical Engineering through studying part time at University whilst working full time.

He decided to join IAgrE to support his professional development and has gained Incorporated Engineer (IEng) status. Reflecting on the CPD processes he says "The framework involved really suited me. Being set deadlines and certain criteria was the best way for me to build upon my knowledge"

"IAgrE were very informative and encouraging. They provided valuable guidance when extra assessment work was required due to my qualifications not being listed on the IAgrE system as their standard acceptance criteria.

The whole process took about 18 months and has helped me to gain professional confidence in my role and to expand my knowledge in areas where I need more experience. This has allowed me to work on larger projects and to take on more responsibility.

My employer has been very encouraging and supportive towards professional development, allowing me to take on a variety of projects to meet the required competence and commitment standard for my professional grade. They have also celebrated my success with press releases and social media."

More information http://iagre.org/cpd

FEG founders (l-r) John Lyons (FEG Ireland), Dr Geoff Freedman and Jim Christie

"A nation that destroys its soils destroys itself. Forests are the lungs of our land, purifying the air and giving fresh strength to our people."

Franklin D. Roosevelt

FOREST ENGINEERING

One of the most wide-ranging and influential specialist groups within IAgrE is the Forestry Engineering Group (FEG) which stages a well-attended Symposium every other year, attended by senior representatives from the UK forestry industry. FEG Secretary **Bruce Hamilton** MIAgrE from Forestry Enterprise Scotland (an agency of Forestry Commission Scotland) reflects on current issues and developments

The Forestry Engineering Group (FEG) within IAgrE was established in 1989 to represent various facets of forest engineering. The group aims to build a healthy, multi-purpose forest industry supported by its own accomplished professionals and it aspires to be the central source of information on forest engineering topics.

WHAT IS A FOREST ENGINEER?

In basic terms, someone who applies the principles of engineering in the forest industry. They are generally involved in the fields of civil, mechanical and process engineering.

The diversity of topics can range from road and bridge building, machinery design and management to the processing end which involves operations such as pulping, sawing and board making.

The forest engineer works in partnership with the forester, each using his or her special skills with either an engineering or biological emphasis to manage the ever-changing forest industry.

The forester will provide the expertise to develop the resource and the forest engineer will provide the expertise necessary to develop the infrastructure and processing systems required to convert the tree to timber products for the market place.

Together, and with other specialist professionals, they will plan, harvest and manage multipurpose forests to the benefit of owners, the public and the environment.

UK FORESTS

Nowadays, about 13% of Britain's land surface is wooded and totals 3.17m hectares (7.8m acres) and of that 18% is in Scotland, 15% in Wales, 10% England and 8% Northern Ireland *(Forestry Commission Report 2017).* 7000 hectares of new woodland was created in 2016-17 with conifers accounting for 54% of the total.

In the early part of the 20th Century, the country's supply of timber was severely depleted particularly after the First World War when imports were difficult, and the forested area bottomed out at under 5% of Britain's land surface. On 1 September 1919 the Forestry Act came into force. This set up the Forestry Commission and gave it responsibility for woods in England, Scotland, Wales and Ireland. Eight Forestry Commissioners were charged with promoting forestry, developing afforestation, the production of timber, and making grants to private landowners. The first Commission trees were planted on 8 December 1919 at Eggesford Forest, Devon.

Of the total UK woodland area, 0.86 million hectares (27%) is owned or managed by the Forestry Commission (in England and Scotland), Natural Resources Wales (in Wales) or the Forest Service (in Northern Ireland), with the remainder in private ownership.

Latest figures reveal that around 17,000 people work directly in the forestry sector, and 26,000 in the wood production sector.

Britain's industry and population uses at least 50 million tonnes of timber a year. More than 75% of this is softwood, and Britain's forests cannot supply the demand; in fact, less than 10% of the timber used in Britain is home-grown. Paper and paper products make up more than half the wood consumed in Britain by volume.

In 2016-7, the UK produced 10.7m green tonnes of softwood and 0.6m green tonnes of hardwood.

The total value of wood product exports in 2016 was £1.5 billion, a 7% decrease from 2015; of which £1.3 billion was pulp and paper whilst the total value of wood product imports in 2016 was £7.5 billion, unchanged from 2015; of which £4.1 billion was pulp and paper.

As a result, the UK is the second largest net importer of timber products in the world after China.

ACCESS, BIODIVERSITY AND SAFETY

The forestry engineers' role is to ensure forests can be accessed safely by providing roads and bridges that are appropriate to the locality.

Forests are not only places of work but are also places for sport, recreation and tourism and engineers always need to look for sensible and pragmatic solutions which both enhance the visitor experience whilst at the same time reducing the risk of accidents.

Engineers also need to communicate with the public to ensure they understand the objectives on any schemes and the challenges that might arise – for there is always a balance to be struck between delivering public access and protecting and conserving all aspects of the natural environment.

The progress and process of engineering projects within a forestry environment is rarely quick nor without considerable challenges and obstacles.

A recent example, outlined at the FEG 2018 Symposium of the complexity of projects was the construction of a new timber haul route at Nether Horsburgh near Peebles under the auspices of Forest Enterprise Scotland, which would serve as a link between the main A72 Galashiels – Edinburgh/Glasgow Roads and Glentress Forest.

The objective was to keep the many visitors who use the forest away from timber traffic as much as possible, thus minimising the risk of accidents and injury. The new forest route also had to accommodate articulated lorries up to 44 tonne.

From the outset many stakeholders and groups had to be included in the consultations including Forestry Commission Scotland, Scottish Environment Protection Agency, Scottish Natural Heritage, Historic Scotland (now Historic Environment Scotland), Scottish Borders Council, Peebles & District Community Council, Innerleithen & District Community Council, Southern Upland Partnership, Tweed Forum, RSPB, Red Squirrels in South Scotland, Scottish Borders Forest Trust, Butterfly Conservation, Visit Scotland and the Deer Commission for Scotland

Factors that had to be taken into consideration including

- Scheduled Ancient Monuments
- River Tweed Site of Special Scientific Interest/Special Area for Conservation
- Tweed Valley Special Landscape Area
- Potential spawning grounds in tributaries
- Existing watercourses including Hope Burn and Dirtpot Burn

- Private water supplies – catchments and infrastructure (pipes, tanks)
- Views from local villages
- Views from the A72
- Landscape character of rounded hills, steep-sided valleys – potentially high visible impact
- Compatibility with local heritage sites including Nether Horsburgh Castle
- Biodiversity on areas of upland heathland habitat on higher ground
- Impact on native woodlands

Other considerations also had to be incorporated including locating the road on the lower slopes of hills, avoid 'skylining' the hills, designing 'hairpins' in the road to minimise the amount of cut and fill and avoiding steep gradients which would not only test lorries but add to traffic noise. The route of the new road should be through woodland wherever possible to provide cover.

Following extensive planning and consultation, the full proposal was submitted in 2014 and approved in 2016 with strict provisos that roads and tracks were to avoid disturbing any special interest sites identified during the initial surveys.

At one point during construction, the main haul route was re-aligned in one place to avoid having to excavate a potential site of interest, only to have to be moved back to avoid a badger sett!

A three year time limit for the job was put on constructing the new timber haul route linking Glentress Forest with the A72, together with a new forest access road, a main spur road including a crossing of the Hope Burn and additional forest tracks to enable woodland establishment and future timber extraction was completed on time – with relations remaining cordial with most neighbours and stakeholders during the whole project according to Forest Enterprise Scotland.

MACHINERY AND TIMBER EQUIPMENT

Whilst engineers are often closely involved during the upkeep and evolution of forests, their main focus is often on the range of machinery and equipment used in timber extraction.

And that often starts with the chainsaw.

The first instance of a machine that we regard as todays chainsaw dates back to the 1830s when a German orthopaedic surgeon, Bernard Heine came up with a device with hand links carrying small cutting teeth (called an osteotome) which he used on bones during his operations.

The first portable chainsaw was developed and patented in 1918 by Canadian millwright James Shand, who let his patent lapse which allowed companies like Andreas Stihl to move into the market with both electric and petrol powered saws. When World War II halted the supply of German saws to North America, new manufacturers sprung up such as McCulloch and Pioneer whilst in Europe, Husqvarna a Swedish rifle manufacturer dating back to 1659, started manufacturing chainsaws in 1959.

In the UK, a talented designer J Clubley Armstrong got together with Stroud based engineering company T H & J Daniels to design and build a range of British built chainsaws under the DANARM name.

The first saws were powered by Villiers 2-stroke engines, from 80cc up to 350cc. The larger models were capable of taking cutter bars up to 7ft in length. Many of the early saws were supplied to War Office specification for use in jungle battle areas.

Around 1954 the DANARM model DD8F Saw was introduced, incorporating the Villiers 98cc '8F' 2-stroke engine. The saw weighed about 28lb and featured a diaphragm carburettor which enabled the saw to be used easily by one man at any angle. The yellow DD8F became a popular brand for British foresters and famous worldwide. However, worldwide competition was increasing with lighter and lighter saws and Danarm ceased production in 1984.

Todays chainsaws, now available as petrol, electric and cordless options, are a far cry from their heavier, noisier, and fuel thirsty predecessors. They are packed with ergonomic features, new materials that make them lighter, advanced anti-vibration components which protect the operator over prolonged use and sophisticated air filtering systems.

And today, forestry companies can remotely keep track of their chainsaw operators through GPS tracking systems that provide information running time, location, service intervals and other data direct to computers or smartphones.

Whilst chainsaws are often the start of the process, timber has then be sorted, collected and hauled and this has spawned a whole separate range of specialist equipment.

Back in 1937 John Deere adapted its Model D tractors which were pushed into service as logging winches. The wheels and seat were removed and wooden skids attached to the front, enabling the winch to be powered from the stationary machine.

From there during the 1940s and 1950s, crawler tractors were used in the steep and often difficult forest terrains.

In the 1960s they were starting to be replaced by articulated wheeled skid-steer machines that provided much greater flexibility.

However as machines have become more sophisticated, global climate change has had a major effect on the environment where machinery is expected to work. In the UK we have experienced higher rainfall and longer periods of "higher temperatures" resulting in higher ground temperatures which is in stark contrast to many of the Northern European countries which rely on frozen ground on which to operate machines.

In addition, engine emission regulations have accelerated during the past 15 years and this has provided constant adjustments on machine design, which together with other design criteria and legislation has also driven weight increases in machine design.

A machinery manufacturer speaking at the FEG Symposium in 2016 said that customer demand now was for *"Stronger, more durable and more reliable machines. The machines should be lighter than currently available and they should offer increased performance on steep ground whilst also offering solutions to enhance soft soil logging capabilities!"*

Today, forestry contractors have a range of real-time mapping systems (such as John Deere's Timbermatic mapping system) which gives operators a real-time production view to the logging site. The data collected by the harvester's sensors and the precise GPS-based location of the felled timber, is automatically transmitted from the harvester to the app for use by the forwarder operator.

The data between the machines is updated through a cloud service, and all the operators working at the same work site can see all the tree species and assortments with the driving routes right down to the individual logs.

The operator can mark the forwarded timber as transported to the storage area, so that the operator of the next shift knows where to start their work. There is no need for an estimate of the volume and not a single log will be left even in a dark forest, for different assortments are shown on the map right down to the single log - even if they are covered by snow.

The operator can choose the desired assortment from a specific area or along a logging route and the map will show the exact volume of that assortment in the chosen area. The operators can also mark special areas on the map - this way soft ground can be avoided when planning the driving route.

The contractor can see exact information about the progress of the work site with displays providing cubic metres and as a percentage, making it easier to plan the timber transports and improve the operation of the entire timber delivery process.

Meet a Member

ALASDAIR WYLLIE IEng CEnv MIAgrE

Alasdair is the agricultural adviser to the Government of Tristan da Cunha, a job he has done since 2016. He lives on the island with his wife Bee and overseas the farming enterprises on the island. He gained an NDA at the Royal Agricultural College in 1966 and after managing farming projects in Scotland, he has worked largely overseas on farm management and development projects.

Tristan da Cunha is an extraordinary place. The island is entirely dependent on shipping and the main revenue-earning product is crayfish. Agriculture on the island is cattle, sheep and potatoes plus some vegetables and a little fruit. My initial brief included a few fanciful ideas but I concentrated on going 'back to basics' in the interests of food security and sustainability.

The main challenges faced can be categorised as logistical, technical, climatic and cultural. Cultural issues have developed as the island has little contact with the outside world and because of its isolation the adoption of new ideas can be restricted.

Part of my work on Tristan da Cunha involves keeping the islanders up-to-date about what we are doing, and why. It is important that I try to develop a general understanding of the steps that we are taking, the advances that we are making, and our overall objectives.

The climate is temperate maritime, but this does not convey the day to day reality of the weather which plays a pivotal part in limiting farming. For example, rains in the last 12 months have resulted in serious flood damage, a combination of erosion and alluvial deposits being washed down from the high ground accounting for the loss of some 10% of the 400 hectares of available pasture land.

The limited land area is poor, boulder strewn and not ploughable. This has become 'pasture' by the colonisation of kikuyu grass and other low performing weed grasses.

Potatoes have been grown on the island since the first settlers. They are grown in small wall-enclosed areas called 'potato patches' and it would surprise all potato-growing farmers around the world to know that the potatoes are grown on the same ground year after year with no rotation.

Living on Tristan da Cunha means you need to be flexible and have a practical approach to life

THE PROFESSIONAL ENGINEER

Recent events have called into question the ethical standards of the engineering community. But the interest of the public must always be paramount says Alastair Taylor.

The professional, be that an engineer or an environmentalist might consider what happens when things go wrong. If anything brings home the need to adopt a professional approach it is those news headlines where something major has gone wrong. Something which makes the public ask the question as to "who" allowed "that" to happen.

Any good professional will think about the application of their skills and knowledge and how they do this in an ethical and proper way.

True professionals will do everything possible to stop the unthinkable from happening in the first place.

Take the Volkswagen emissions scandal (sometimes referred to as dieselgate) which began in September 2015, when the US Environmental Protection Agency (EPA) issued a notice of violation of the Clean Air Act to the German car maker.

The agency had found that Volkswagen engineers had intentionally programmed turbocharged direct injection (TDI) diesel engines to activate their emission controls only during laboratory testing which caused the vehicles' nitrogen oxide (NOx) output to meet US standards during regulatory testing, but then emit up to 40 times more NO_x in day-to-day driving.

Volkswagen had deployed this programming software in about eleven million cars worldwide between 2009 and 2015 – all of which had to be recalled for modifications. The reputational damage was immense, Volkswagen's stock value plummeted, sales volumes fell – and the CEO responsible was arrested and charged.

Most of us would consider that the diesel engine is the prime power unit for agricultural engineering. So it should obviously concern us all, that one major manufacturer has done much to damage not only its own reputation, but also the reputation of diesel engines.

CODE OF CONDUCT

As professional engineers we commit ourselves to following a code of ethics. In principle this calls for us to be honest and truthful.

Members of the IAgrE are signed up to the Institutions Code of Conduct. This document can be viewed on our web site at http://iagre.org/codesofconduct. In addition, we are registered with Engineering Council and are also required to obey the Engineering Council's Statement of Ethical Principles.

It is important to bear in mind that our Institution's Code of Conduct is the minimum standard that is expected of us. It also makes it clear that the interest of the public is always paramount. In effect any work that we carry out as engineers should be in the interest of the public regardless of the country in which we are operating.

Professionalism is as much about conduct as it is knowledge. As someone once put it, the best way of understanding the meaning of professional is to understand its opposite, namely the word "amateur".

Although there are many well-meaning people, many of whom are very well trained and do a great job, the true professional should always understand the wider need for attitudes and behaviours which are synonymous with their professional status.

They will appreciate that belonging to an professional body such as IAgrE and rubbing shoulders with fellow members is an excellent way of keeping at the top of their game.

In the past, many Engineering Technicians, Incorporated and Chartered Engineers, together with Chartered Environmentalists have signed up to registration as a professional.

The best employers, technicians, engineers and environmentalists continue to do so. In an ever more complex and litigious world, they are wise.

At this time only a few engineering sectors expect people to be professionally registered but given IAgrE's work with plants, animals, the land and the environment, how long will it be before our own industry sets the standard? It would only take some sort of environmental or public health disaster. Perhaps it is time to get registered anyway.

HEALTH AND SAFETY

A snapshot of agricultural machinery safety across the decades is reviewed by **Mike Whiting** MIAgrE and **Andy Newbold** FIAgrE of Newmac Limited, a specialist agricultural machinery health and safety support and advice business www.newmac.org.uk

It's almost impossible to have a discussion today about agricultural machinery without including a reference to safety. Providing a safe working environment for all in the industry is the top priority given agricultures accident record.

To understand how safety has evolved within and become a fundamental part of machinery design, it's relevant to consider the influencing factors over the past 80 years.

Firstly, that within the famous "Maslow's hierarchy of needs", food is an essential element of human existence. The 1947 Agriculture Act provided a springboard for ramping up agricultural output after the scarcities of, and immediately after the 2nd World War. In amongst the race to plough up every acre of fertile land to plant crops, one of the first references to considering safety in machinery design is noted circa 1964. A glance through the book charting the history of Wrest Park, the home of the National Institute of Agricultural Engineering (NIAE) refers to what is still to this day probably the most important element of agricultural machinery safety; the development of the tractor cab safety frame.

It's a sobering thought to consider that in 1966, over 50 operators lost their lives in overturning incidents. The test and development concepts applied in the safety cab design show the importance of combining practical field testing with good engineering principles.

The picturesque landscape of Ivinghoe Beacon, near Buckinghamshire provided the "British Standard" hill, where a sacrificial tractor fitted with a prototype cab was put into a simulated roll over incident.

The aims were to identify which areas of the frame would take the impact loads, and most importantly how a single roll over incident would impact on the continued safe operation of the tractor. Collaboration with our Swedish colleagues provided the NIAE & MAFF (Ministry of Agriculture, Fisheries and Food) with the knowledge and information to develop the familiar "pendulum frame" test rig which was a point of reference for any visit to the Bedfordshire based research facility.

HEALTH AND SAFETY ATTITUDES

The emphasis on physical testing of components to verify safety is supported by the industry's determination to maximise productivity. Referring again to archive material, the essential reading material for any farmer with an interest in machinery during the 70's and 80's was "Power Farming". A magazine stuffed full from cover to cover with updates on new equipment and agrochemical products which would make farming more profitable.

An article in the July 1975 edition from a subscriber raises a query with his fellow colleagues asking whether he could justify retro-fitting a cab to his existing "naturally air-conditioned" 14ft cut combine harvester.

What is interesting to note is the letter recognises the hazards associated with such equipment (2 deaths and 22 accidents in 1973), although it does challenge the investment of a few hundred pounds to reduce the potential

risk of developing farmers lung. Another article refers to the cost of temporary staff for herding cattle and sheep for routine testing, and the development of race systems for improved efficiency.

What do these articles tell us? Principally that health and safety was included in the mix of priorities for machine designers, as was a desire for improved efficiencies. The fact that it provided some additional comfort was a bonus.

ENGINEERING A SAFETY REVOLUTION

Once the driver was seated safely within the tractor cab safety frame, the next step was to improve the operating environment, notably the exposure to noise and vibration. Most experienced tractor drivers in the late 40's and older will be familiar with the resonance vibrations from tractor cabs of the 70's era. A trait typically induced when the engine revs matched the frequency of the structure, exacerbated by a few loose mechanical fixings.

The early anechoic chambers at Wrest Park were constructed from straw bales, which although were "variable" in their accuracy of data recording, provided a starting point for noise measurement. Many hours of research was undertaken for assessing the psychological impact on the tractor driver when undertaking different tasks such as field operations or operating over a test track to simulate road use.

The economic requirement to operate machinery for extended hours to meet seasonal workloads meant that operator comfort became a focal point. The development of the XL cab by International Harvester pushed the boundaries beyond the agricultural industry into the automotive sector. The iconic curved rear window section, tan interior control centre being the result of a multi-million dollar investment project delivered by the luxury car maker Porsche.

Massey Ferguson and John Deere were also in the comfort game with their 3000 range and SG "Sound Gard" cab respectively.

The farming forefathers from the 1940's would have turned in their graves if they'd found out we were actually enjoying ourselves whilst burning diesel in the field. Although there was still one big restriction in agricultural mechanisation, the maximum road speeds of tractors on the public highway.

Sir Anthony Bamford had this challenge firmly in his sights, and the development of the JCB Fastrac was put into action. The kingpin of the engineering process was Ray Clay. Ray's previous experience and knowledge from developing off highway machinery and suspension systems were essential ingredients to form the basis of the yellow and black liveried prototype.

As to why no other manufacturers had attempted such a specification was simple. Attempting to plough with a suspended rear axle was a non-starter, hence the Fastrac employing a multilink system which provided traction in the field and a much smoother ride on the tarmac at speeds exceeding 20mph.

A number of innovative specifications in the areas of steering and braking which didn't follow the traditional tractor design rules provided the basis for a utopia commercial road haulage and farming workhorse. The essential element being that when the operator applied his right foot to put the anchors on, the tractor and trailer or implement combination came to a controlled stop.

STANDARD APPROACH

The majority of implements operated within the mainstream agricultural, horticultural and hobby farmer arena's are covered by the EU Machinery Directive 2006/42/EC. This permits a "self-assessment" approach to confirming compliance under the "CE" accreditation.

Although there is a roadmap for engineers to follow which ensures safety is maintained from the drawing board through to prototype testing, this is achieved via EU harmonised standards (hENs) which provide specific detail on individual components and overall equipment design and provide practical guidance to reduce risk.

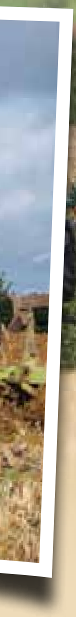
Ag-sector machinery has evolved in both physical size and operational complexity, which has meant that the expert committee members who draft the standards have had to keep pace with their reviews and updates.

There is one essential piece of the transmission jigsaw where the "hENs" demonstrate their importance, the power take off shaft. Regardless of machine colour, the requirement for the familiar lemon shaped steel shafts and connecting yolks with secure guarding has been a consistent element of the majority of machine specifications.

As with tractor safety frame testing, practical assessment of the robustness of the guard is confirmed by putting the transmission assembly and guarding through operational tests, including angular positions ensures that maximum load scenarios are considered.

As hydraulic power transmission systems improve in efficiencies, combined with electrical control networks, the PTO shaft can be replaced for more efficient and safer operating specifications. As to delivering consistently high torques for running baler pick-ups and power harrows, this can be provided by methods other than the PTO shaft - and remains on the industries "to-do" list.

Another area where standards and advancements in technology have progressed to further reduce risk to the operator is in air filtration and machinery cab design when applying agrochemicals. The requirement to ensure accurate application rates and providing a safe working environment is essential to ensure the industry presents a positive image to the wider community.



WORKING TOWARDS A TRULY SAFE INDUSTRY

Although it's a current "hot topic", driverless tractors have been on the agenda for decades. Research work undertaken at Wrest Park in the 1970's by Owain Harries and Mike Warner developed an almost completely autonomous combination of a two-wheel drive tractor and a three furrow reversible plough.

The incentive for raising the concept further up the priority list is the demand for a more efficient agricultural sector. Although if we do move towards autonomy, do accident rates reduce as a consequence?

A driverless cultivation or seeding system is still likely to get stuck in a field if the weather conditions turn wet, so what safety precautions would a remote operator need to take as they approached it to recover the unit? The requirements for extremely reliable safety circuits which always fail to "safe mode" will keep engineers busy for the next few decades.

In addition, the research and development work undertaken by the "hands free hectare" team at Harper Adams University and other associated project teams will be essential in simulating such fault scenarios in a controlled environment.

Any incident investigation requires root cause analysis to establish the causes. It's a well-known fact that within any industry which involves people and machines, lack of training or understanding has been a contributor in causing an accident. This can be a symptom of having to operate to tight deadlines with a very constrained budget.

What we need to harness from the potential for increased levels of automation is the available time to properly train, coach and motivate staff to ensure that they can become agricultural professionals.

However no amount of technological expertise will ever replace the skills developed from getting on a tractor or other self-propelled harvesting unit and having a go yourself. In addition, scenarios such as the 2017 harvest where more combines were running on the 15th September rather than the 15th August needs to be considered.

The fact that the crops were cleared wasn't just the result of the machines capacities, it was the ability of the management and operators teams to exploit every ounce from their own skills, decision making and determination.

In addition, after many hours of staring at the laptop screen, there are countless numbers of people, who would quite happily jump on a tractor after 5pm and lose their trials and tribulations from the day with high horsepower at their fingertips and something equally power hungry coupled up behind.

The accessibility to automation therefore needs to be managed appropriately, providing economic savings and safety, without turning agriculture into a grey and binary based affair.

Image credits: *JCB Fastrac (www.farmingphotgraphy.co.uk), others courtesy of David Laley*

TIMELINE OF SAFETY DEVELOPMENTS

April 1959: First standardised test methods approved for assessment of tractors by OECD. (Organisation for Economic and Commercial Development)

Early 1960s: NIAE undertook hillside rolling tests using remote controlled tractor to assess manufacturer's safety cab specifications.

1st September 1970: Legislation required all tractors supplied on the UK market were required to be fitted with a safety cab.

1st September 1975: All new tractors sold into the UK to be fitted with a safety cab in which the noise level at the driver's ear did not exceed 90dBA.

1978: Department for transport issues "Code for Agricultural Trailer braking systems"following work undertaken by NIAE

Mid 1980s: Tractor manufacturers develop and commence production of "Q" type quiet cabs.

1991: JCB's project codenamed 130 is put into commercial production and launched to the market under the name of "Fastrac". The tractor incorporated HGV specification braking and suspension systems whilst also retaining the ability to perform routine farming tasks.

1995: Fendt introduce the concept of a continuously variable transmission to the tractor specification with the Favorit 926, which offers improved control of the unit, particularly on the road when towing maximum load capacities. The feature was operated via the use of a multi-function joystick.

2002: Power take off shafts: HSE publish research report on the development of strength tests for tractor/machine interface standards. Development of the current EU harmonised standard for PTO designs EN 12965.

2018: Introduction of updated Mother Regulations (EU 167/2013) for tractor and interchangeable equipment type approval. These recognise the increase in size, potential speed and technological advancements in agricultural machinery design and requirements for safety specifications.

POST HARVEST TECHNOLOGY

What happens beyond the farm is just as important as the growing and harvesting process. IAgrE CEO Alastair Taylor considers what part agricultural engineering can play in reducing waste and improving efficiencies

If sheaves, threshing machines and storage clamps were commonplace at the birth of IAgrE, there is little doubt that the progress in harvesting technologies has seen significant change over the past 80 years.

Self-propelled combine harvesters output now exceeds 70 tonnes an hour and can cover ground areas unheard of by past generations. With the introduction of stripper headers and rotary threshing mechanisms, together with yield mapping systems and complex control systems, harvesting technology is at an advanced stage.

The same goes for root crop harvesting with self-propelled potato and sugar beet harvesters capable of lifting, cleaning and conveying several rows simultaneously.

Across the agri-food sector, farmers have the capacity to produce more food, more quickly . . BUT, and it is a huge BUT. . .

Worldwide, around one third of the food they produce is lost between farm and fork – and a significant amount of energy inputs are embedded in these losses. In developing countries, most food losses occur during harvest and storage. For this reason, improving post-harvest activities in developing countries is an important way to increase farmers' incomes.

Food losses are often caused by a lack of access to energy for adequate post-harvesting operations, such as drying, storage and processing, as well as a lack of transportation and distribution.

In more developed countries, there is no doubt that the precious harvest is completed with greater accuracy, better handling, higher emphasis on maintaining quality and at greater speeds than anyone would have ever thought a generation or so ago.

Yet the post-harvest process has never been more important. The United Nations Food and Agriculture Organisation (FAO) breakdown of food systems losses shows some startling statistics with even the developed countries in Europe wasting around 12 per cent in the handling and storage stages with similarly high percentages at the production stage

Clearly the post-harvest processes of handling and storage present Agricultural Engineering with opportunities as well as challenges.

The effective storage of products post-harvest is at the heart of Global Food Security as well as efforts to reduce losses at the production stage is where Agricultural Engineering will contribute. It is interesting to note that the processing of food has seen efficiency gains across the world so engineers working with food processing such as cereals and dairy should be proud of their achievement. IAgrE has members working in this area.

SUGAR BEET PROCESSING

In engineering and technology circles there has been much focus on sensors and telemetry systems to monitor crop drying and storage. From air flow to anaerobic activity, hot spots to humidity, a myriad of information is now available to help the farmer, grower and processor to know whether the crop is in optimum conditions. Advances allow the monitoring of storage shelf life of tomatoes using an electronic nose technique and going forward, smart packaging will allow for much closer tracking of product traceability and optimisation of supply.

In the future, Agricultural Engineers will be more closely involved with the integrated systems approach as identified so well for sugar beet processing. This will demand engineers who can think in terms of the bio-system and step outside of the traditional engineering paradigm where specialists stick within their own area of expertise.

At British Sugar's Factory in Norfolk, these are very much on display.

Wissington is a beet sugar plant established in 1925, as part of British Sugar. The plant supplies 420,000 tonnes of sugar a year in various formats, extracting it from the sugar beet grown around the East of England. However, describing Wissington simply as a 'sugar factory' is something of a misnomer.

The team at Wissington constantly evaluate their operation to valorise previously wasted energy and material flows. The result is a factory that doesn't just produce sugar, but 12 different saleable products.

Some of the co-products are more obvious than others, and the approach shows an open-mindedness to new ideas. At Wissington, the economies of scale are most pronounced, and offer the best example of how this type of expansion can improve the resilience of the business.

When the 3 million tonnes of beet

are delivered each year, it is in need of a good clean. The soil and stone removed during this process isn't seen as a waste problem but is in fact sold at a volume of 150,000 tonnes a year, and a third of this is sold under the Topsoil brand - part of British sugar. In addition, the 5,000 tonnes of stones that come out of the process are sold as aggregate.

After washing, slicing and diffusing, the sugar beet goes through a purification process, which uses lime and CO2 to remove the non-sugars (impurities).

The lime used to purify the sugar is turned into LimeX, another saleable product commonly used by growers to correct soil acidification, as well as on brownfield sites and in the production of mushroom casing. This endeavour makes British Sugar the leading supplier of liming products to UK agriculture, displacing quarried limestone and chalk.

Wissington is also home to the UK's first bioethanol fuel plant, where British Sugar - reacting to the supply and demand of their core product - use some of the extracted beet sugar syrup to produce around 55,000 tonnes of renewable fuel each year.

But one output that Wissington shares with most manufacturing processes worldwide is CO2. Through an innovative approach, British Sugar has enabled surplus carbon dioxide at the plant to be used as a resource put to productive use. One major customer, Air Liquide, uses the gas in a variety of applications such as industrial refrigeration.

GRAIN STORAGE

On a different scale, the storage of grain cereals has benefitted from engineering innovation and developments "light years" from the past storage system of canvas bags and air ventilated hoppers. Continuous dryers, whilst energy dependent and no substitute for the positive forces of natural drying, mean that the moisture content of grain can be reduced quickly thus allowing long term storage – often upwards of twelve months.

The balance of energy inputs versus quality outputs remains a conundrum for engineers but with modern monitoring and control systems, this has become a much better process.

A 21st century grain handling facility will include many technological advances to ensure clear traceability, sampling, testing and automatic movement of products. Conveyer, augers and lifters benefits from integrated control systems with computer controlled movement such that a multitude of tipping points for different products can allow simultaneous movement of products around the site.

Galvanised steel bins, roof pitches which match the angle of repose of the produce thus allowing maximum space utilisation, automatic sampling and remote monitoring are all tools which help the precious harvest to be stored in optimum condition.

At the Dorset grain store of Dutch-owned Cefetra Wessex, it has a state-of the art operation that can store up to 70,000 tonnes of grain which it often holds for up to 8 months before trading to a multiple array of customers for feeding stuff, brewers, food stuffs and fuel at home and abroad. "Nothing is ever left to chance" says Simon Wilcox, UK Manager for Farm Grain Origination. "From the original sampling of incoming loads, through constant monitoring of our 'grain-stock' to the final samples taken from outgoing loads. Our aim is to deliver a cleaner, better product to customers, and that can mean removing excess chaff from 'dirty loads', blending grain to meet nitrogen targets or to meet specific customer requirements.

The biggest cost to everyone in the grain storage business is the rejected load by a customer because it doesn't meet their instructions. The transport costs alone can be horrendous, so we have to get it right first time"

The research community continues to investigate how crop storage can be improved. Technology from the aeronautical industry is harnessed to help with efficient storage, regulating even airflow through the grain store to maintain quality. The so called "smart" grain store can adjust its own parameters in order that air ends up in the right place, where it is needed and its impact will be greatest.

There is no doubt that Agricultural Engineers have come a long way with developments to support post-harvest technologies – and there is plenty more to focus upon.

British Sugar plant at Wissington

IAgrE

1938
Institute of British Agricultural Engineering (IBAE) formed with offices in Wilton Street, London Founder Presidents

1930

1942
Move to Gordon Square, London

1945
First branch formed in Norfolk

1940

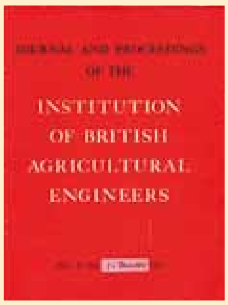
1946
Council elected 3 farmers and Douglas Bomford

1947
National Institute of Agricultural Engineering (NIAE) moves to Silsoe

1950
Offices move to Portland Place, London

1955
Offices move to Buckingham Gate, London

1950



1958
IAgrE launches first Journal

1959
Offices move to Queen Square, London

1962
IAgrE Presidential Badge created

1960

1960
IBAE becomes the Institution of Agricultural Engineers (IAgrE)

1965
Offices move to Penn Place, Rickmansworth

1970
Journal becomes IAgrE magazine

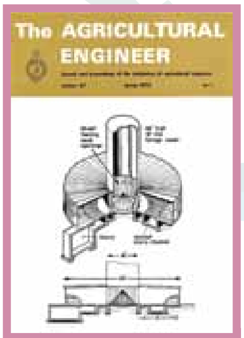
1972
IAgrE joins Engineers Registration Board (ERB) Douglas Bomford Trust formed

1970

1974
Offices move to Silsoe

1979
HRH Prince Philip attends Douglas Bomford Lecture at Silsoe

Timeline



1971
IAgrE joins Council of Engineering Institutions
IAgrE magazine becomes The Agricultural Engineer

1978
Douglas Bomford Lecture given by Lord Mayor of London at Mansion House

1981
Engineering Council formed

1984
Engineering Council takes over ERB

1980

1985
IAgrE wins McRobert Award presented at Buckingham Palace to John Matthews

IAgrE becomes nominated and authorised body of Engineering Council

1988
IAgrE Golden Jubilee

1989
Forestry Engineering Group formed

1993
European Society of Agricultural Engineers (EurAgEng) formed

1990

1996
The Agricultural Engineer becomes Landwards

Horticultural Engineering Group formed

1997
New IAgrE logo

2002
IAgrE debates, but rejects name change

2004
IAgrE becomes authorised body of Society for the Environment

2000

2007
Landbased Engineering Accreditation (LTA) scheme launched

2010
Offices move to Bullock Building, Cranfield University

2011
Milkingequipment manufacturers join LTA

2012
IAgrE responds to Professor Beddington's Foresight Report

2010

2018
IAgrE celebrates 80th Anniversary with AGM at Wrest Park, Silsoe

IAgrE PRESIDENTS 1938 - 2018

1938 -1947
Lt Col Philip Johnson CBE DSO

1947-1948
Dr Cornelius Davies

1949-1951
C B Chartres

1951-1953
F E Rowland

1953-1955
D P Ransome

1955-1957
D R Bomford

1957-1959
J M Chambers

1959-1962
W J Nolan

1962-1963
C A Cameron Brown

1963-1965
W J Priest

1966-1967
J H W Wilder CBE

1967-1969
T Sherwen

1969-1971
H C G Henniker-Brown

1971-1972
C Culpin OBE

1972-1974
J A C Gibb OBE

1974-1976
J V Fox

1976-1978
T C Manby OBE

1978-1980
J C Weeks CBE

1980-1981
J C Turner

1981-1982
R F Norman CBE

1982-1984
J G Shiach

1984-1986
B A May

1986-1988
J Matthews CBE

1988-1990
Dr B D Whitney

1990-1992
D M Walker

1992-1994
J B Finney CBE

1994-1996
R J Godwin

1996-1997
M J Dwyer*

1997-1998
R J Godwin

1998-2000
B J Legg

2000-2002
G J H Freedman

2002-2004
C D Mitchell

2004-2006
P L Redman

2006-2008
P C H Miller

2008-2010
R E Robinson

2010-2012
P N Leech

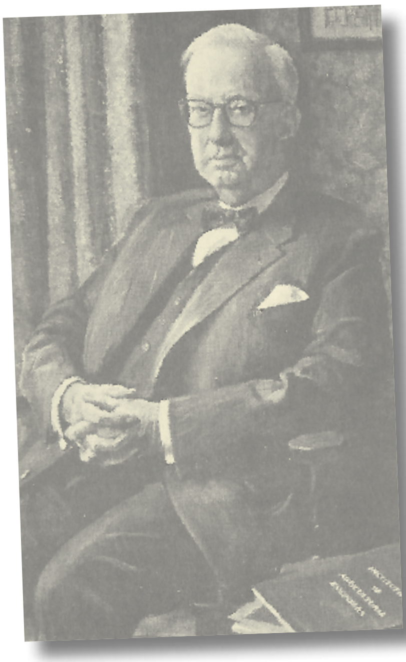
2012-2014
A C Newbold

2014-2016
M G Kibblewhite

2016-2018
R J Merrall

2018 -
R J Rickson

* Michael Dwyer passed away during his term as President, and previous President Dick Godwin stepped in as Acting President for the remainder of his term



LEFT: 1938 Founder President: Lt Col Philip Johnson

ABOVE: 8 Past Presidents pictured in 1962: Seated (l to r) C B Chartres, Lt Col Philip Johnson, Dr C Davies. Back row: D P Ransome, D R Bomford, W J Nolan, F E Rowland and J M Chambers

IAgrE Secretaries/ Chief Executive Officers

1938
A S E Ackerman

1938 – 1944
C Horton

1944-1949
G D Betty

1949-1950
D St J Magnus

1950-1951
W E Fitzhugh

1951 – 1963
R E Slade

1963 – 1971
J K Bennett

1971-1973
H N Weavers

1974-1985
R J Fryett

1985-1991
G E E Tapp

1991-1992
J Dennis

1992-1997
M Hurst

1997-1999
J H Neville

1999-2013
C R Whetnall

2013 -
A J Taylor

ABOVE:
President: Professor Jane Rickson

ABOVE: 10 Past Presidents pictured at Wrest Park 2018: (l to r) C D Mitchell, R J Merrall, A C Newbold, R J Rickson (current President), P N Leech, M G Kibblewhite, J B Finney, R J Godwin, P L Redman, P C H Miller, R E Robinson (R F Norman present but left before photo)

Promoting Professionalism

LANDWARDS

BIOSYSTEMS
ENGINEERING

CONFERENCES

1938
2018
IAgrE

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CONTINUOUS
PROFESSIONAL
DEVELOPMENT

KNOWLEDGE
EXCHANGE

NETWORKING

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