SOUE News

Issue 8 Summer 2009

Society of Oxford University Engineers

Welcome to the eighth issue of SOUE News

Compared with our Centenary issue last year, this one is quite a bit shorter. Our feature articles include Colin Tyrrell recalling 36 years of designing roads, mainly for Hampshire, and how attitudes to new roads have changed over that time. Now he has become a planning inspector, or as he puts it, the poacher has turned gamekeeper. Colin Axon writes about the new Oxford-based James Martin Institute for Carbon and Energy Reduction in Transport, and the prospects for it.

Professor Alexander Thom (Head of Department 1948–61) spent his later years surveying prehistoric stone circles and coming to some surprising conclusions about the intellectual and technical abilities of those who built them. Archaeologists, after initial enthusiasm, turned sceptical. David Witt reports some recent attempts to re-affirm his conclusions.

And we have the usual reports on the previous year's events, including last September's Jenkin Lecture (by David Clarke), and the accompanying talks by Daniel Walker and Richard Osborne. And there is a summary of John Beddington's Lubbock Lecture in June.

The Jenkin Lecture this year is on Saturday 26 September, by Simon Watts on radar, and we are having a dinner the previous evening. Details are on an enclosed slip.

In This Issue

Head of Department's Report 2008–2009

Guy Houlsby

First of all, may I introduce myself, Guy Houlsby, as the new Head of Department. I have taken over from Professor Richard Darton, and am very grateful to him for all the work that he has done, ensuring that the Department was in very good shape indeed when I took over in July 2009. Richard will be busy over the next couple of the years, as he takes up the presidency of the European Federation of Chemical Engineering in 2010. I am not new to the Department, having worked here since 1980, so in fact I know many of the readers of this newsletter. I am a Civil Engineer, with my main interests in offshore problems. Most recently I have devoted much of my time to renewable energy projects, and have a particular interest in tidal power.

Achievements

In late 2008 the results of the Research Assessment Exercise were published — a process eagerly anticipated in the Universities. The grading system used this time was a little more complex than had been used before, but Oxford was ranked second in the UK for General Engineering, with 85% of our activity rated as "world leading" or "internationally excellent". We have to acknowledge though that our rivals in Cambridge (a much larger Department) did exceptionally well, and have set us a very tough target to beat next time. We achieved some revenge, however, a few months ago when Oxford was ranked in The Guardian's survey as the top University in the UK to study General Engineering.

Our undergraduates continue to prove that they are some of the very best in the country. At the national SET awards in October 2008 Vicki Barker was named as Best Maritime Technology Student of the Year for her project studying extreme waves off the coast of Norway, continuing a run of success at these awards (for the previous two years we won the award for best Civil Engineering student). A team of three Keble students (Rebecca Threlfall, Tze Yeung Cheung and Ben Mather) won the Spring 2009 NECR Challenge. Jamie Darling won the Pulsed Power Award for his work on high power RF generation, and Jamie Curry won the inaugural Fugro GEOS award from IMarEST for his project on propagation of long waves.

It is pleasing to see our graduates going on to successful careers. Hanna Sykulska-Lawrence, a 2004 graduate from the Department, was named as the IET Young Woman Engineer of the Year. Josh Macabuag won the ICE's Graduate and Student papers competition with his work on use of polypropylene straps to prevent collapse of adobe buildings during earthquakes.

We have a cohort of very talented and motivated postgraduate students working on a bewildering array of topics. The 2009 Cornhill Prizes for DPhil projects in Biomedical Engineering were awarded to Alistair Hann for his work on monitoring of patients in high dependency care, and to Alexander Rowley for work on investigation of the way blood flow is controlled by the body. These projects illustrate some of the very important contributions engineers are making to medicine, with our Institute of Biomedical Engineering being at the forefront of research. Our students have also demonstrated their business acumen — Yimin Zhou and Zhen Yu, the "Oxford Vision Team", beat 186 other teams to win the fourth annual China–UK Business Competition. Jessica Whittle was just one of the many postgraduates presenting their work at conferences — she won first prize for her presentation at the IStructE Young Researchers' Conference.

Dr Constantin Coussios has been elected as a Fellow of the Acoustical Society of America, and Dr Mark Thompson held the first Raine Medical Foundation Fellowship at the University of Western Australia. These are just examples of many accolades received by our staff over the year.

Academic Staff News

September 2008 saw the retirement of Professor David Clarke, one of the longest serving members of the Department, who had filled almost every academic role in the Department from undergraduate through to Head of Department. He will be well known to most of the readers of this newsletter. I am delighted to say that he will be replaced as Professor of Control Engineering by David Limebeer, who joins us from Imperial College in October 2009. In September 2009 Professor Rodney Eatock Taylor will be retiring as Professor of Mechanical Engineering, although he will be maintaining an interest in some research projects for some time to come, as well as taking up a visiting post at the National University of Singapore.

A number of Departmental Lecturers have joined us in the last year. Dr Stefano Utili works on applications of the "distinct element" method in geotechnical engineering. Dr Vito Tagarielli is working on composite materials and Dr Manish Arora on the use of ultrasound for therapeutic purposes. Dr Alex Lubansky works in chemical engineering. Dr Anja Drews, who was joint winner of the prestigious Arnold Eucken Award for young chemical engineers, will be leaving us in September to take up a full-time post in Berlin, after all too short a stay as Departmental Lecturer.

Three new University Lecturers will be joining us in October: Dr Budimir Rosic (Turbomachinery), Dr Gari Clifford and Dr Haiko Schifter (both the latter in the Biomedical area).

Professor Martin Williams is currently Senior Proctor, which means that for the time being we are seeing less of him in the Department, as the University has the benefit of some sound common sense from an Engineer as Proctor for the fifth time in recent years (if I have counted correctly).

Buildings

The opening of the Institute of Biomedical Engineering, within the Old Road Medical Campus development at Headington, was announced last year. I can report that research there is now in full swing, with the build-up of activity there being much more rapid than we had anticipated. The latest success is the award to a team led by Professor Lionel Tarassenko of an £8m grant for research on development of "Personalised Healthcare" from the Wellcome Trust and EPSRC.

Many readers will be familiar with the Turbomachinery laboratories located in the Southwell Building (the old power station at Osney). The move to the nearby "Axis Point" building that will provide a much more modern and satisfactory base for the Turbomachinery group is well underway, but there is so much complicated equipment to be re-housed that the move will take most of the next year to complete. We are also currently advertising the Donald Schultz Professorship of Turbomachinery.

For many people of course the iconic building that represents the Department is the Thom Building — loved and hated in almost equal measure, no-one could accuse the building of being dull. It is, however, showing its age, and there are particular problems with the cladding and the facade. We are exploring options ranging from minimal repair through to complete rebuilding, but shall probably end up with a compromise involving recladding and some internal refurbishment. We shall try to retain the best features of the building, and also hope to improve the entrance area.

The Future

The Department has ambitious plans for the future. We recognise that we must expand to be able to compete at the very highest level, and are just beginning to shape our plans for the new directions we shall take. Of course Oxford is not immune from the worldwide economic pressures, and like others the University is feeling the pinch financially at present. This may affect the pace of change that we can achieve, but I am confident for the longer term.

Finally can I wish all past members of the Department, and our many friends, all the best. Please keep in touch with us, as we very much value our links around the world.

August 2009

The 21st Jenkin Lecture, 20 September 2008: Control and the Coriolis Mass-Flow Meter

Professor David Clarke — report by David Witt

David started by giving us a large-scale example of the need for mass-flow measurement — the supply of fuel oil to a large container ship. The oil is sold by weight, but currently the measurement is often just of its volume — just a glorified dip-stick, of doubtful accuracy. The money involved is substantial, so there is clearly a need for something more precise.

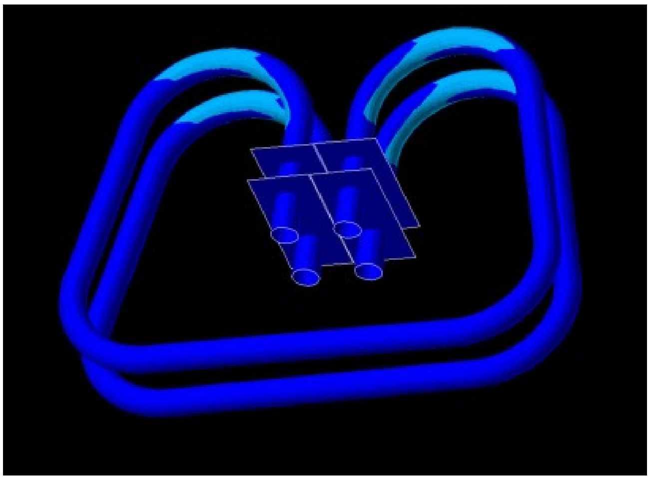

Figure 1: Arrangement of mass-flow meter

The Coriolis mass-flow meter measures fluid mass-flow (kg/s) by passing it through an arrangement of tubes which are undergoing angular vibration about an axis perpendicular to their length (Figure 1). The flow goes through both upper and lower tubes in the same direction, but their vibration is in opposite directions, driven by vertical "voice-coil" actuators acting up on one tube and down on the other at the left and right ends of the straight portions in the front of the picture.

Consider flow along one of these straight tube lengths at the front of Figure 1 (see Figure 2).

The Coriolis acceleration term is $\theta \dot{r} \dot{\theta}$, and is upwards for the directions shown (consider what happens to the vertical velocity of a fluid particle as it passes along the tube). The force to produce this acceleration of the fluid must come from somewhere, so there is a downward force on the tube. This force is proportional to the mass-flow rate, and is in phase with the sinusoidally varying angular velocity $\dot{\theta}$. The tubes are thus set into a vertical vibration mode, superimposed on the angular mode. The design is such that the angular vibration is made to occur at the resonant frequency for that mode. The resonant frequency for vertical vibration is lower than for the angular mode (by a factor $1/\sqrt{3}$ according to a simplified model, but slightly different in practice), so the vertical mode is excited somewhat above its resonant frequency by the Coriolis force. Its velocity therefore lags the driving force by 90°. Both frequencies will vary with the density of the fluid in the tubes, but the ratio between them should be constant. So if the vibration always occurs at the resonant frequency of the angular

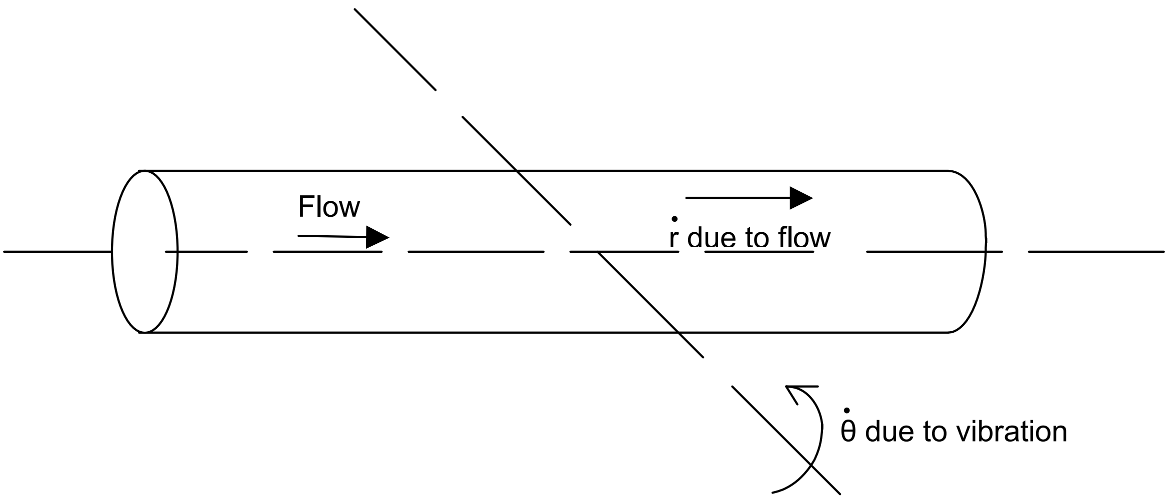

Figure 2: Flow along one of the straight tube lengths at the front of Figure 1

mode, the calibration factor should have a calculable relationship to this frequency, which of course can easily be measured.

The vertical velocity at each end of the tube is measured (electromagnetically). There will be a differential-mode component (one end up and one down) due to the angular vibration, and a common-mode component (up and down together) phase-shifted 90° from the other, due to the vertical vibration. The mass-flow rate can be shown to be proportional to the (small) phase difference between the combined velocities at each end.

The main topic of the lecture was about how they (David and his research group) had devised a much-improved method of controlling the amplitude of angular vibration. The main disturbance to it occurs at the start of flow, when the tubes are only part full, and there is a lot of damping due to the sloshing of the fluid. To drive a resonant system at its resonant frequency, one needs a force in phase with velocity, which is equivalent to "negative damping". The initial approach was therefore to introduce a non-linear velocity-dependent force, with a positive term proportional to velocity and a negative term proportional to velocity cubed. This would give negative damping at small velocities, reducing and eventually changing sign as the amplitude increased. This does indeed control the amplitude, but not well enough, and introduces undesirable harmonics. So they tried an "amplitude-control loop", measuring the amplitude and varying the amount of negative damping with a simple proportional-plus-integral controller. Again, it works, but not well enough (Figure 3a). The shape of the step response varies with the amplitude of vibration, and there are undesirable overshoots and undershoots.

The cure for the amplitude-dependency of the step response is to base the gain-control loop on the logarithm of the amplitude, rather than on the amplitude itself. The overshoots and undershoots are then similar at all amplitudes, and are the natural result of a zero in the amplitude-control transfer function introduced by the proportional-plus-integral control algorithm (Figure 3b). The solution is simply to cancel the zero with an equivalent pole, by putting a simple lag transfer function immediately after the set-point input. The system is now as represented by the block diagram of Figure 4.

This was successful, but the response was at first a little slow (Figure 3c). Speeding it up by a factor of ten with suitable changes to gain

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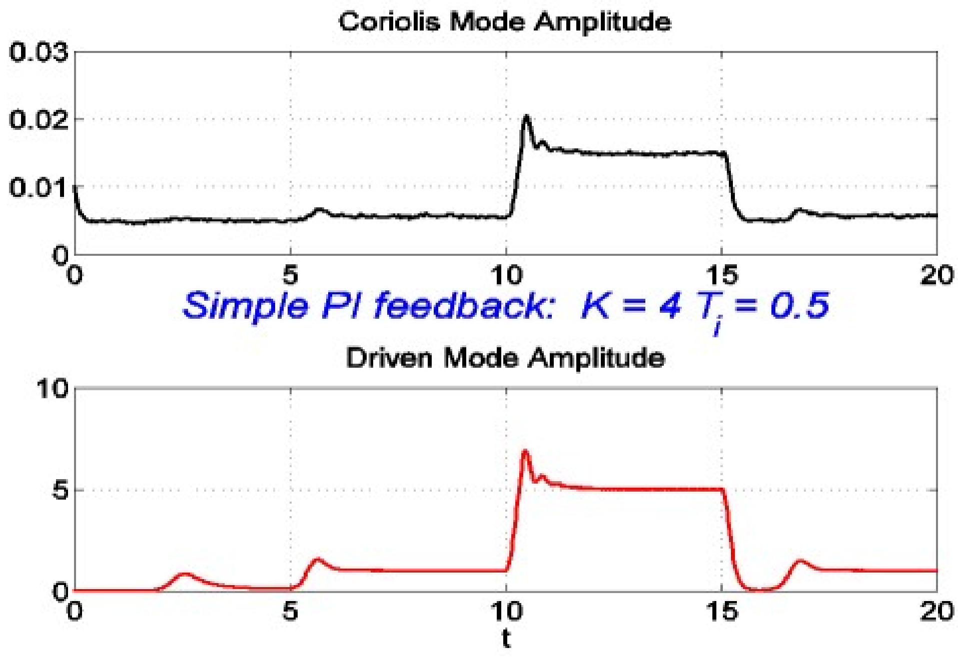
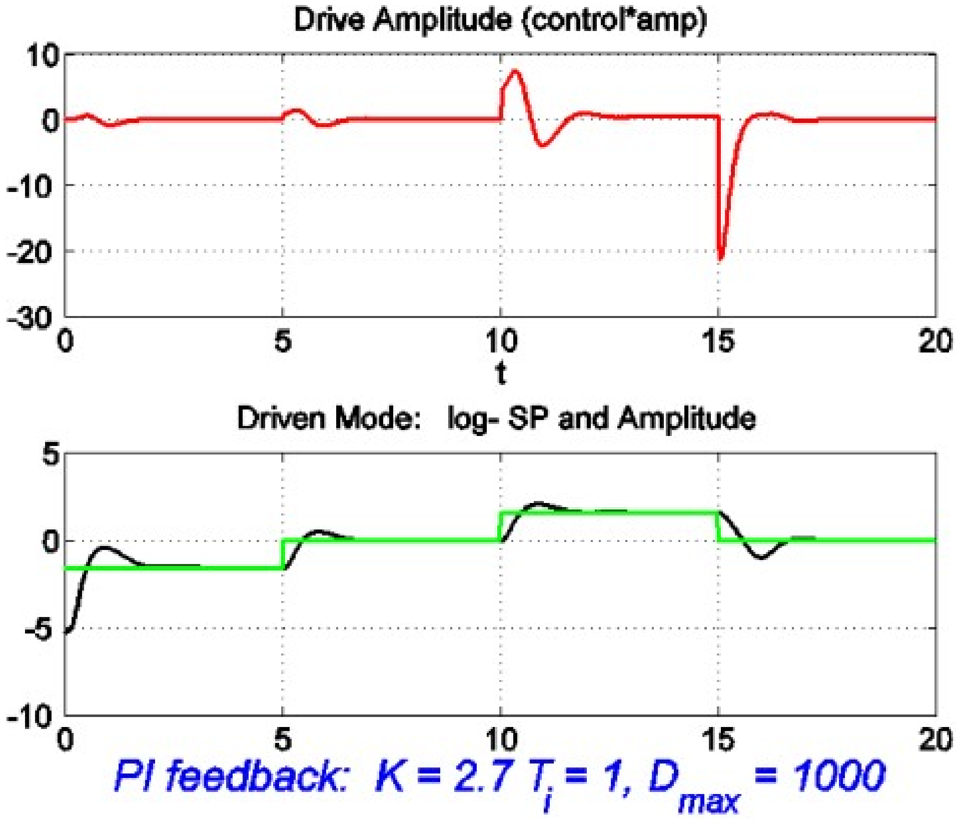
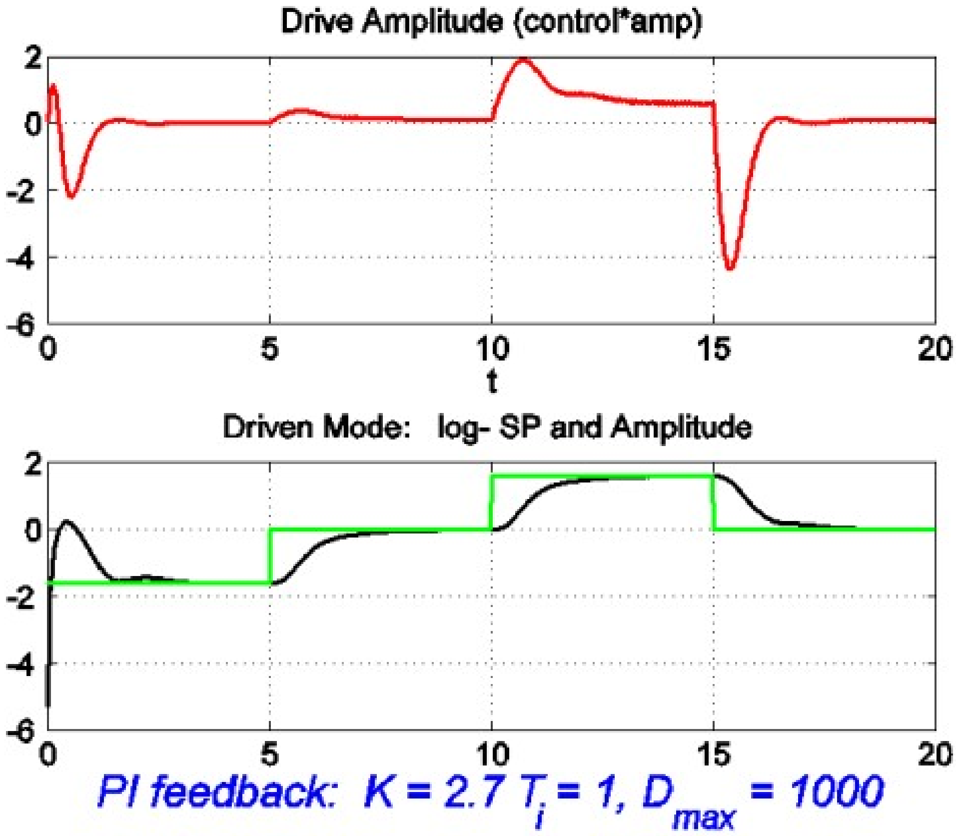


Figure 3a: Amplitude-control loop behaviour

The 21st Jenkin Lecture, 20 September 2008: Control and the Coriolis Mass-Flow Meter cont.





Figures 3b (top) and 3c: Log-amplitude control behaviour

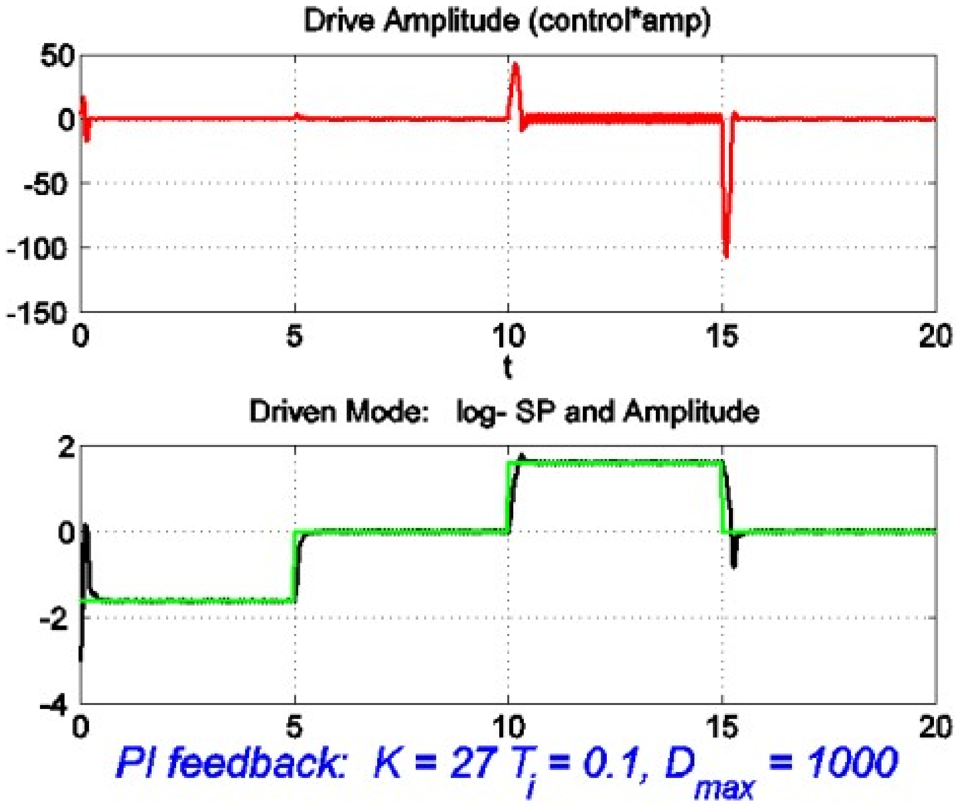


Figure 3d: Log-amplitude control behaviour after speeding up

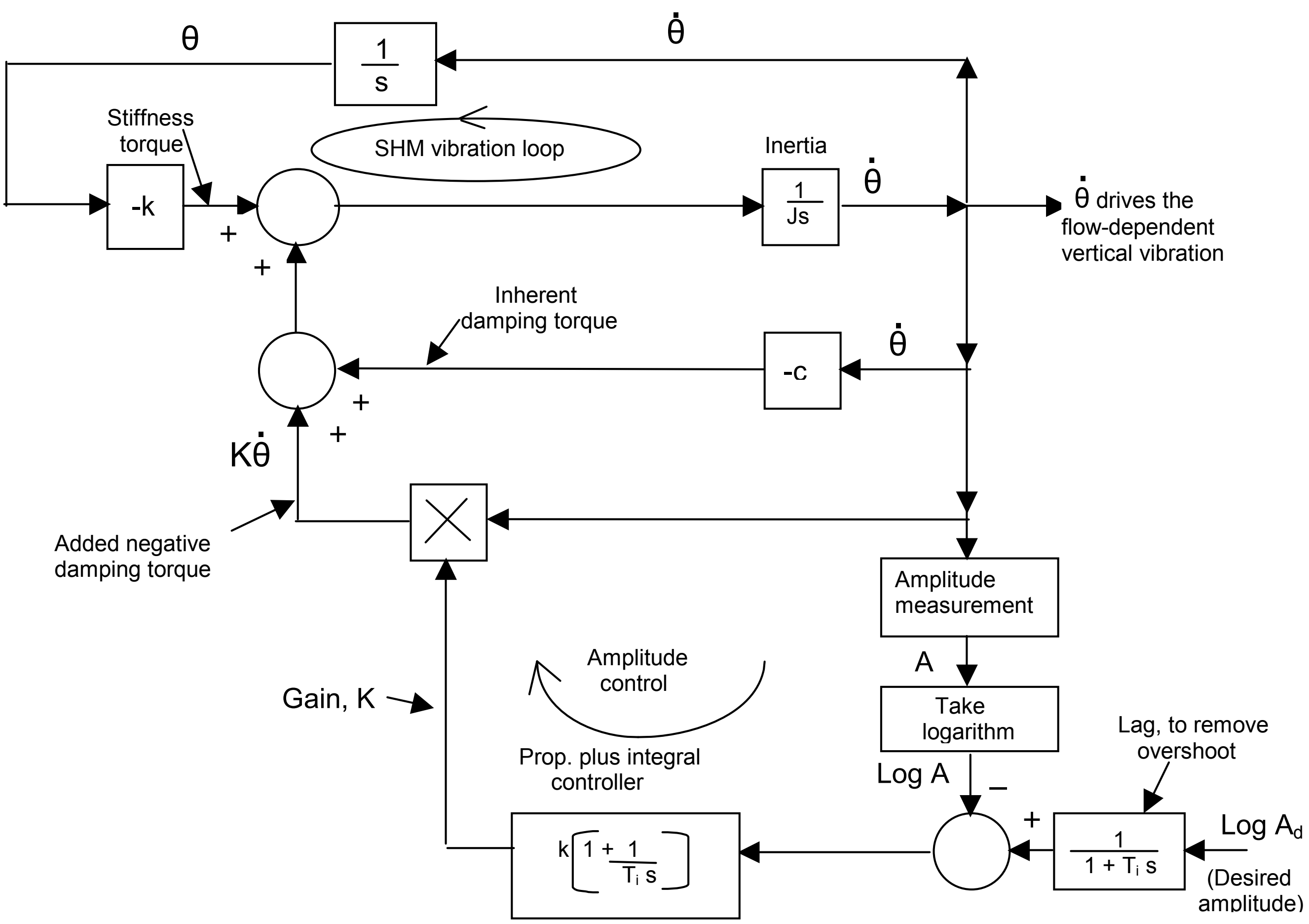


Figure 4: Block diagram of overall system

The 21st Jenkin Lecture, 20 September 2008: Control and the Coriolis Mass-Flow Meter cont.

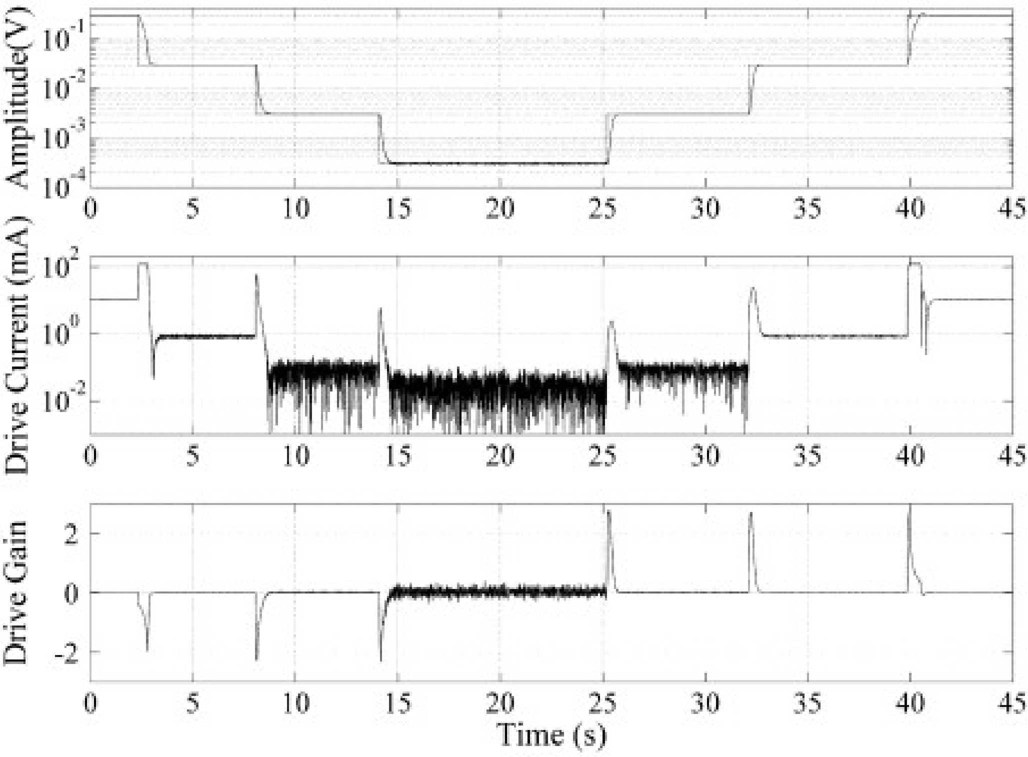


Figure 5: Behaviour of actual system

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and time constants brought overshoots back again at large amplitudes (Figure 3d). This was traced to saturation of the integral term (the finite range of a D-to-A converter). When this was cured the response was similar and well-behaved over three orders of magnitude of amplitude variation, as shown in Figure 5 for the actual system (the traces in Figure 3 are of simulations). At the smallest amplitude the current signal is noisy, but the amplitude is still behaving as it should. A comparison with a simple analog controller that had been used earlier showed substantial improvement.

For fire-safety reasons, when measuring the flow of fuel oil they are not allowed to put more than 25 mW of power into the drive coils. So if the damping increases significantly (air in the tubes), the amplitude must be decreased, but not allowed to vanish altogether, or the flow measurement will be lost. Hence the need for well-behaved control.

The complete algorithm, together with the other systems needed by the meter, were implemented by a combination of specialist circuit boards (DACs, ADCs, FPGAs etc.) and a host computer. A/D and D/A conversion was done to 24 bits, at a 48 kHz sampling rate. The amplitudes of the sinusoidal velocities were calculated, one cycle at a time, by a Fourier method, and the driving sinusoids were digitally synthesised. The design has led to a commercial product, mass-flow transmitter CFT50, built in the USA.

The work had won the Coriolis team the IET Measurement Prize for 2007. The team members are D Clarke, M Henry, M Tombs, F Zhou, M Duta, M Zamora, R Mercado, M Machacek, J Bowles and P Fair.

The lecture was supported by some impressive demonstrations, computer-driven displays from two projectors, and an actual vibrating tube set from a mass-flow meter, quite noisy if the amplitude of vibration was allowed to get too large.

A Petrol Engine That Can Switch Between Two-stroke and Four-stroke

A short talk by Richard Osborne preceding the 2008 Jenkin Lecture

Richard is with Ricardos at Shoreham and the work described had been undertaken as the result of the now widespread desire to reduce CO_2 emissions. One way to do this in a motor vehicle is to use a smaller engine operating nearer to full load under normal cruise conditions. It may then have inadequate full-load torque for acceleration or hill-climbing, but this could perhaps be remedied if the engine could switch from a four-stroke to a two-stroke cycle when high torque was required. For example, a six-cylinder engine would then have six power strokes per revolution instead of three. The likely torque/speed curves of such an engine might be as in Figure 1.

In two-stroke mode the admission of the new charge and exhaust of the old one have to take place simultaneously in a rather short time around bottom dead centre. To that end, the exhaust valves have been made larger than the inlet valves, and the engine is supercharged. This requires a shaft-driven compressor rather than a turbocharger, since although the latter does indeed raise the inlet manifold pressure, the pressure drop across the turbine also raises the exhaust pressure. A shaft-driven compressor gives a positive pressure-drop across the whole engine, and thus speeds up both inflow and outflow. A radial compressor, more efficient than the traditional Roots blower, has been used, and indeed turbochargers have been used in addition, presumably to increase the mass flows. The fuel is injected directly into the cylinders, primarily to avoid loss of charge in the two-stroke mode.

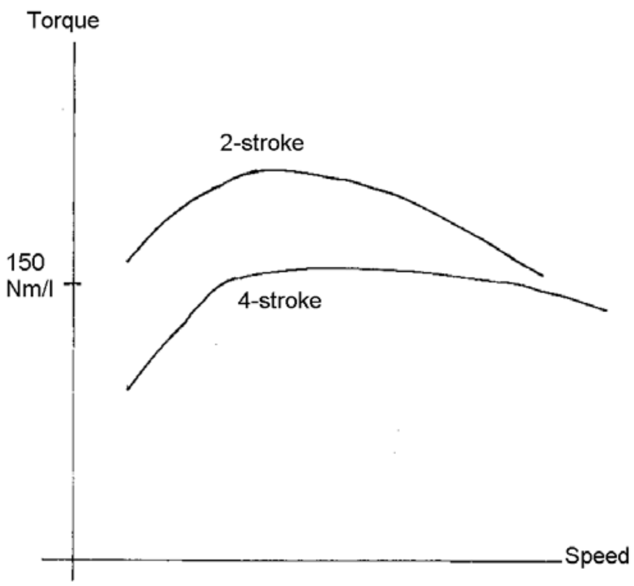

Figure 1: Likely torque/speed curves of engine

The valves are top-entry poppet valves, (side-entry ones would short-circuit the charge), and in the experimental prototype are operated electro-hydraulically rather than by a camshaft, so that the timing can be easily varied.

The engine runs successfully, with performance much as expected, though it takes two seconds to change from four-stroke to two-stroke. On a simulated driving cycle for a 1815 kg vehicle in which a 2.1 litre two/four-stroke engine replaced a 3.5 litre conventional four-stroke, the fuel consumption and CO_2 emission were reduced by 19% or 27% (depending on the cycle being simulated).

There is still a lot to do, including the development of a mechanical valve drive system. The intention is to demonstrate the use of a V6 engine in a Jaguar.

The work is being supported by the Department of Trade and Industry, with various collaborators.

Reference: Osborne RJ et al, *Development of a multi-cylinder two-stroke/four-stroke switching gasoline engine*, 2009 IMechE Conference on Low Carbon Vehicles

Increased Production and Reduced Risk in the Gulf of Mexico During the Hurricane Season

A short talk by Dan Walker preceding the 2008 Jenkin Lecture

Dan had been involved with the Thunder Horse project in the Gulf of Mexico since July 2007, and described what he had been working on.

Thunder Horse is a moored oil and gas production platform (Figure 1) floating above a 2000 m depth of water. There is a complex well-head structure on the sea floor, connected to the platform by a vertical drill-pipe, the "riser". But a hurricane, quite common in this area as we all know, can cause motions of the platform of a magnitude likely to break the riser at its top end. It can then fall on to the well-head, risking substantial and very expensive damage to it. So if a hurricane is predicted, the riser has to be disconnected from the well-head and pulled up to the platform, where it can be dismantled and stored in short lengths. But this part of the Gulf of Mexico carries a strong circulating current, which swings the riser to one side as soon as it is disconnected from the well-head. If the current exceeds 1 knot, as it often does, the riser swings so much that it fouls the lower parts of the platform, and it is then impossible to raise it (Figure 2a).

One solution tried was to fit a fairing to the drill-pipe, thus changing its cross-section from a circle to a more aerofoil shape, with less drag. But there may be no more than two days' notice of a hurricane, so the need to remove the fairing when raising the drill-pipe made this solution impractical.

The solution they actually adopted was a movable collar on the structure at about sea level. The collar can be opened up, moved to grasp the riser, closed, and then moved to centralise it. A ring of polyurethane rollers permits the riser to be pulled up through the collar with little friction (Figure 2b). But the riser is still subject to lateral force from the current, so centralising it at sea level means

Figure 1: The Thunder Horse platform

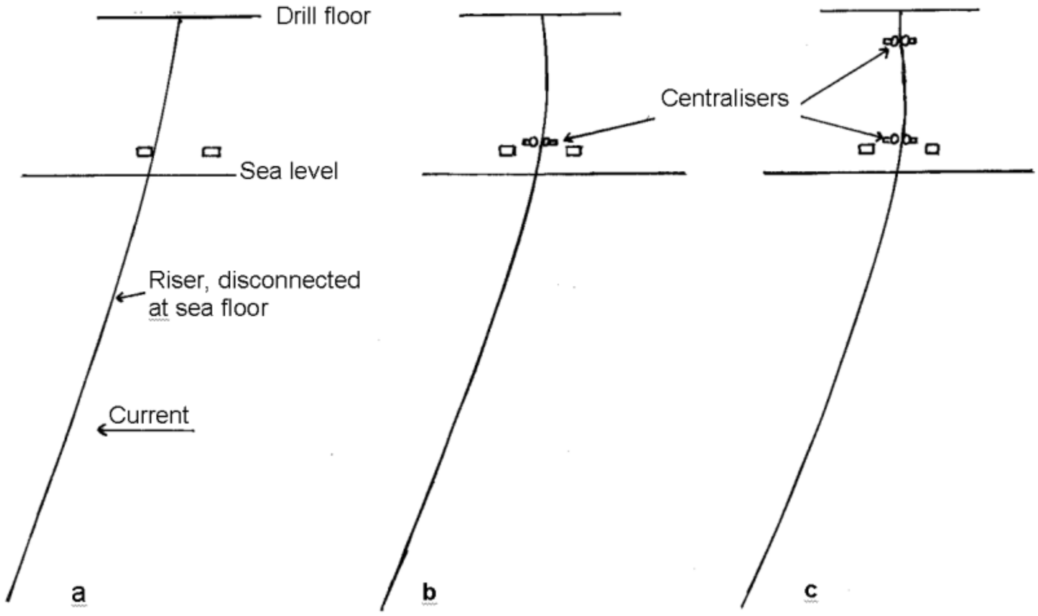

Figure 2: Centralising collars to control lateral riser position

Figure 3: The lower collar

that it still has substantial shear force in it above that. So a second collar is fitted further up, near to the drill floor, to correct this (Figure 2c). The topmost section of the drill-pipe can then be removed safely. Figure 3 is a photograph of the lower collar, a substantial piece of machinery, as can be seen.

The riser had to be modified too, since in its original form it was much wider at the joints between the sections. Extra tubular bits were added to make it of uniform diameter, so that it runs through the collars without jamming.

The new arrangement works well, and the riser can now be raised in any current up to the highly unlikely speed of 3 knots. The risk of riser failure in a hurricane has been much reduced, and there is increased confidence that it can be raised successfully at short notice, thus extending the time available for drilling.

The 35th Maurice Lubbock Memorial Lecture, 18 June 2009: Science, Engineering and Technological Challenges for the 21st Century

Professor John Beddington

Professor John Beddington is Chief Scientific Adviser to the Government and Head of the Government Office for Science. As he said, he is not an engineer, but a population biologist from Imperial College. He confessed that his new job, to advise the Government on science generally, would be an impossible one but for the presence of the other Chief Scientific Advisers that most Government Departments had now appointed (the Treasury excepted!), and their supporting staffs, who between them included several engineers, social scientists and natural scientists, with whom he was in regular contact. And there were the research councils and engineering and scientific institutions which he could also consult.

He then showed us a slide listing eleven global challenges to the 21st century, but explained that he did not propose to deal with all of them!

1. Population growth and urbanisation

These were particularly critical in Asia and Africa, less so in the rest of the world. Total world population was growing at six million per *month*, and was predicted to reach about 8.3 billion by 2030. But all of this growth was likely to take place in urban population, while the rural population actually declined. This growth was likely to lead to famine and disease. But in most of the world prosperity would increase, in that far more people would have an improved standard of living. There would thus be a much increased demand for a diet richer in meat and dairy products, for more travel, and more energy etc. Food production and energy demand worldwide were both predicted to rise 50% by 2030, much more than the population increase.

2. Water

One third of the world's population faces water shortages already, and this will certainly increase. About two-thirds of the use of fresh water now is by agriculture, mainly by rather inefficient "peasant agriculture". Shortages are going to lead to such use being "priced", leading to a greater pressure on people to leave agriculture and move to the cities. He defined the vulnerable parts of the world in this respect as those using more than 40% of the available fresh water (the rest either evaporating or running into the sea). These regions are going to increase, particularly with the rising temperatures from climate change, to include most of North and South Africa, the Middle East and India. Steven Chu, Head of the US Department of Energy, has predicted that even in California, agriculture may have to cease in 25 years.

3. Climate Change

A 2 °C rise in average temperature is now unavoidable whatever we do, and it will be 4 °C if we fail to cut our CO_2 emissions by 40%. Crop yields will fall in many areas, though they may rise in higher latitudes. The Arctic may well become ice-free in the summer, which would open up opportunities to exploit its resources (and to squabble about them!). But melting glaciers and ice-caps will raise the sea level, and tundra regions may start to give off methane, thereby enhancing the greenhouse effect. And much else will occur too.

A modest average temperature rise of about 2 °C in 2003 led to an estimated 35,000 deaths in Northern Europe. By 2040 such temperatures (40 °C) will be the summer norm. The London Underground could well become intolerable, though Scotland might perhaps become cooler (and wetter!).

4. Ocean Acidification

The pH of the oceans is believed to have hovered around 8.1–8.2 for the last 25 million years, but if much of our increased CO_2 emissions were to dissolve in them, they could become seriously acidic, e.g. a pH of 7.7. The consequences for eco-systems and food supplies *could* be very serious, though, as the lecturer admitted, our knowledge here is very sketchy. It is thought that the last time the oceans became that acidic, 50% of the organisms in them became extinct. But that was a *very* long time ago.

5. Conflicts

By 2030 (the lecturer's chosen cut-off date) we are going to need 50% more food, 50% more energy (from *clean* sources), 30% more fresh water, *and* we have to adapt to climate change. Only last year, when cereal prices suddenly rose by 200%, there were riots in e.g. Africa, Bangladesh and the West Indies. There will be conflicts over water in the future, one hopes not between two nuclear powers! When some areas become uninhabitable, either being flooded by rising seas or becoming too hot and dry to live in, the inhabitants will want to move elsewhere. The inhabitants of more favoured lands are unlikely to welcome their arrival.

6. Getting our greenhouse gas emissions down

The UK Climate change Committee has recommended that, as compared with 2005, greenhouse gas emissions should come down by 80% by 2050, and by 21% or 31% (depending on international agreements) by 2020. Electricity generation will have to be virtually carbon-free. The most obvious ways to achieve that are nuclear, wind and CCS (carbon capture and storage), this latter still being in the development stage. Worldwide, CCS is particularly important, since coal is plentiful and cheap in developing countries like China, India and South Africa. Should nuclear fusion turn out to be practical, it will be extremely valuable, and the potential rewards from it justify almost any conceivable level of research investment.

Among other possible energy sources (tidal power etc.), biofuels could be very valuable, both in reducing the use of fossil fuels for transport and in increased energy security for many countries. But it has to be done properly, not on land that could more usefully grow other things. The Brazilian approach with sugar-cane is better than the US one using grain feedstock. But whatever it is, the feedstock has to be transported in bulk, and Brazil's transport network is being found to be somewhat lacking.

Water will have to be used much more efficiently, especially in agriculture, for example by using sensors to give each plant the water it needs, rather than just spraying it indiscriminately and wastefully over the whole field. African agriculture in particular could benefit from such techniques.

To maintain adequate food supplies, the technology of genetic modification is going to be essential. Most of the world is quite happy to use it, but Europe has some irrational prejudice against it that it is going to have to lose. For example, a type of rust that can destroy a wheat crop is gradually coming here from the Middle East. There is no cure for it, but a genetically-modified wheat could be resistant to it. Productivity can be increased in other ways too. We were given an illustration from Brazil, where they now get two crops a year, with the machines planting the second crop following only an hour behind those harvesting the first one.

All these problems are interconnected, and need to be tackled together.

There is still lots of uncertainty about the *detailed* consequences of climate change. For the UK regions, we can predict with reasonable confidence up to about 2030, but after that? And elsewhere, how much will the flow of the rivers Zambezi and Limpopo be reduced? Will the Sahelian drought break? Will we get more frequent El Niños? And so on. We do not know.

Highway Design — Then and Now

Colin Tyrrell (Merton 1964–67)

1967 was not a bad year to become a road builder. The first motorway, the M6 Preston bypass, had opened on 5 December 1958, with the first substantial length of M1, the 67 miles from Watford northwards, opening a year later in November 1959. By 1967, much of the uprights of "H" shape of the M1/M5/M6 in the Midlands were in place, though the tricky bit in the middle did not follow for a few more years.

Further south, not much had been done except for isolated lengths of M4 including the West London elevated section and the first Severn Bridge. The M2 was there, and so was a short length of future M20 around Maidstone.

There were no motorways in Hampshire, where little other road building had taken place since World War II. Design for the future M3 had started, and construction of the A27 Havant Bypass and A33 Otterbourne/Chandlers Ford Bypass was under way though the roads had not yet opened.

Against this background, I set off for interview for a job with the County Surveyor's Department in Winchester. I shared a car with three other Engineering Science students. Much to our surprise we were all offered unconditional places as Graduate Trainees, and started the following August together with five graduates from other UK universities.

It was a different era — all our design work was done in imperial units, most calculations were done using a slide-rule or tables of seven-figure logarithms, and surveying was done using traditional theodolites and tapes. Together with a colleague from Leeds University, I was drafted into the bridge office to help with the design and drawings for a set of three high-skew steel box bridges for the M3 at Popham, just south of Basingstoke. I remember that he was amazed when I asked him what a bending schedule was — it was not a term I had come across during my three years of Engineering Science at Oxford.

We produced our technical drawings in pencil on large sheets quaintly sized in imperial units as double elephant. These were then transformed into silk purses by a formidable team of women tracers who drew in Indian ink on to a stable linen base to produce the masters suitable for the dyeline printing process of the time.

The finished linens came back to us for checking or alteration. On one occasion, I was so embarrassed by a late change due to my error that I decided to make the alteration myself, rather than confess to the tracing pool. I borrowed the motorised eraser they used — similar to an electric drill holding a stick of erasing abrasive. Before I realised what I had done, I had erased right through the linen, leaving a hole in the drawing and a quantum leap in my level of embarrassment.

There was one Anita electronic calculator in the office, which we would queue up to use. These early machines, with a full matrix keyboard and a display of twelve cold-cathode numerical display tubes, were manufactured locally in Portsmouth. They were the size of a typewriter, but were so much quicker and more accurate to use than the mechanical calculators, log tables or slide rules that they replaced. Within a very few years they themselves were entirely obsolete, with the introduction of small hand-held calculators on every desk.

With the detail design for M3 complete, I was transferred to the South Coast Trunk Road design office in Southampton for some preliminary design. This was the first scheme to be designed in metric units — I soon forgot how to convert 7¾" to decimal feet in my head, but had to learn to divide feet by 3.2808312 to get to metres, a conversion factor which remains in the front of my brain some 40 years later. The other big news of the time was that the South Coast Road was now to be a motorway — the M27.

My first major site was the M3 contract for which I had produced some of the bridge drawings, where I was appointed as Assistant Resident Engineer. It was salutary to see the steel-fixers struggling to achieve the framework of large reinforcing bars for the concrete which on my drawing looked so straightforward. I had not realised how unwieldy a large diameter bar could be when it had to be fixed in three dimensions.

Setting out the M3 across many miles of green fields, and ensuring that it was located exactly within the areas of land acquired in the Compulsory Purchase Order, was a skill which my short surveying course at Oxford had not fully prepared me for. Our week of surveying in the Cumnor Hills was a highlight of my first year. The redoubtable Brigadier Bomford, who had been Director of Military Survey in Burma during the war, was our tutor. He started off teaching us all the basics including the use of the plane table to produce direct mapping. After a morning of following him around the fields as we added stations to our individual plane-table surveys, we stopped for lunch. Having eaten his meal, the Brigadier made a discreet move towards some adjacent woodland to answer a call of nature. One of our number who went on to have an illustrious career jumped up, hoisted his plane table, and made off after the Brigadier, only to return shortly afterwards in a state of some embarrassment.

I was working at Popham, just south of Basingstoke, right alongside the old Roman Road. At the time, I was reading the biography of Thomas Brassey, the Victorian railway contractor who built the section of London and South-Western Railway which passes nearby. Whilst he was supervising the works he lived in Popham before moving southwards to Winchester as the works progressed. As I was living in Winchester and travelling up the old Roman Road to Popham to work, I felt some connection with those who had preceded me in building links from London to Southampton.

Unlike the M3 which ran alongside much of the existing A30/A33, the section of M27 I moved to next forged a new route across the Test Valley to the northwest of Southampton. This was the time of the three-day week and rocketing oil prices. The first led to an extended construction period and the second led to a decision to change from a flexible blacktop carriageway to a rigid concrete one. We all had to learn quickly about the complex paving train which formed the complete carriageway in one pass. The process was very different from the multi-layer way a blacktop road was laid, and left no margin for level error.

I was appointed Resident Engineer on my next project, the A27 Lewes Bypass in East Sussex. This was one of the last road schemes to be almost universally welcomed by the community it was designed to serve. The narrow centre of Lewes had been plagued by heavy trunk road traffic, and the bypass had been long awaited. Building a new embankment across the flood-plain of the River Ouse was something of a challenge, given the compressible ground and resulting stability problems. It was 1976 — the hottest summer of the century — and we were transporting 1 Mt of chalk from a deep cutting in the adjoining South Downs. I made a particular effort to keep local residents informed as to what we were doing and why, and I was amazed at the low level of complaints we received even though the inevitable chalk dust made parts of the city look as if they were under snow. When the autumn rains finally arrived, we had two failures of the new embankment. One slip may be regarded as a misfortune; two looks like carelessness, even though it happened just outside the length that had been carefully instrumented to monitor stability.

I had enjoyed my ten years on site enormously, but I accepted that I would have to return to the design office to progress my career. It was at a time of enormous change in design methods and assessment tools, as well as the start of a period when road-building was becoming much less popular.

Environmental assessment of roads had previously been an implicit rather than an explicit part of road design. Most engineers worked closely with their colleagues in the planning department to ensure that new roads were sensitively designed and located where they would cause the minimum of environmental damage. However, there had been some mistakes. The insertion of roads

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Highway Design — Then and Now cont.

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into city centres had in some cases been particularly insensitive. For instance, at the opening of the A40(M) Westway in west London in July 1970, the residents of Acklam Terrace threatened to blockade the road where it ran very close to first floor windows. In those days, there was no power or duty to compensate residents of property which was not physically affected, and the Ministry of Transport refused financial help. At Westway, the tape cutting was only briefly interrupted by protesters who made their point and moved on at police request.

During the 1970s and 80s environmental assessment techniques for highways expanded rapidly, first as part of national best practice and then in 1985 as a result of a European Directive. In 1973, the Land Compensation Act provided a statutory basis for compensation for injurious affection as a result of new roads, and in 1975 the Noise Insulation Regulations came into force. Methods for traffic forecasting were improving, and economic assessment using cost-benefit techniques became more widespread. These did at least serve a useful purpose for comparison between road options, even if the absolute figures over the 30 year assessment period proved to be more suspect.

However, none of this was enough to satisfy the increasingly vociferous anti-roads lobby. Public Inquiries into major road schemes, which in the early days had only taken a few days, became increasingly confrontational, with some objectors apparently convinced that disruption was the most effective way of making their case. In Winchester, there was the spectacle of the M3 extension Inquiry where the Police were called to eject the headmaster of Winchester College. He was intent on saving Winchester's water meadows from further erosion by road building, though they had already been impacted by construction of the Didcot, Newbury and Southampton Railway in 1895 and by the original Winchester Bypass in the 1930s.

He got his way, and in the reassessment of the M3 route in the early 1980s it was agreed that it should be realigned away from the water meadows to run in deep cutting through Twyford Down. Somewhat ironically, although the amended proposals had a reasonably easy passage through the Public Inquiry, they led to even further protest during the construction phase. In the design office in Winchester (now privatised as part of Mrs Thatcher's transfer of design staff from county councils to consultants), we became accustomed to running the gauntlet of angry protestors outside the office.

However, I never did see the parallel of my profession with that of a concentration camp guard, as one protestor screamed at me as I returned from lunch. The first time the protestors broke through security they occupied the ground floor of the office and padlocked themselves to the desks of those wicked promoters of car supremacy: the engineers working on public transport proposals. Those of us upstairs in the motorway design office found this rather ironic.

I think the Winchester College headmaster was probably right about the M3 route, but you may not share my view that the damage caused through Twyford Down was outweighed by the benefit to the water meadows and to the setting of Winchester which resulted from the removal of the old bypass. The railway was closed in the early 1960s, so now there is no major transport obstacle (except perhaps the Itchen Navigation) between Winchester Cathedral and its earlier spiritual counterpart of the magnificent hill fort of St Catherine's Hill. The Centre for Sustainable Transport at Cambridge University has a paper at www7.caret.cam.ac.uk/twyford_intro.htm which in my opinion gives a balanced view of the story.

The demonstrations outside our office continued during the construction of the Newbury Bypass, which was also designed in Winchester. However, we had it a good deal easier than my colleagues on the site, who among other depredations had to put up with being bombed by urine bags released by the protestors in the trees.

It seemed to me that this was no way to carry out a proper debate on the roads programme. I had taken a few projects through the Public Inquiry stage, and, as well as enjoying the intellectual challenge of presenting a case and being subject to cross-examination, I thought it was a much better forum for intelligent discussion than trying to respond to the shouted insults of protestors.

The Planning Inspectorate, which provides the inspectors for Roads Public Inquiries, had traditionally recruited mainly senior military men on their early retirement from the armed forces. Typically such men had a broad experience, a natural air of authority, and the knowledge and judgement of a successful generalist. However, there was felt to be a need for greater expertise in detailed environmental assessment and in technical matters such as traffic modelling and highway alignment.

The Inspectorate decided to recruit more specialist staff for the task, and in 2003 after 36 years of being a poacher I changed sides and became a gamekeeper. I find this much more to my liking. I enjoy becoming totally immersed in one scheme at a time. I find dealing with barristers and controlling the running of an Inquiry stimulating and involving. Weighing up contradictory evidence and coming to a recommendation can be fascinating, and I obtain particular satisfaction from teasing out the justification for proposals, and sometimes backing the individual objector against the combined might of the promoting side.

Three things worried me when I became an Inspector: the requirement to keep at arms length from all sides, the expectation that the Inspector at least will keep his jacket on, and the worry that after lunch in a hot stuffy hall my eyelids might droop. I have managed to deal with the last two by ensuring that the hall is always well ventilated and, if air conditioned, kept at a chilly 19 °C. The requirement to keep aloof from personal contact I find more of a problem. Throughout my previous professional life, I have enjoyed teamwork and the social aspects of working either on site or in a large design office. But this loss is small compared with the job satisfaction which comes from playing a key role in the assessment of projects.

Everything has changed in the 42 years I have been involved with road design. Computer analysis has replaced the use of slide rules and calculation sheets for structural design; CAD has replaced the hand-drawn drafts which were beautifully traced by the formidable ladies from the tracing pool; road alignment is computer defined using a three-dimensional mathematical model rather than by arcs, straights and transitions drawn on a piece of paper; setting out is done by GPS (global positioning system) and EDM (electronic distance measurement) instead of the methods that Brigadier Bomford taught me.

Design methods and tools have improved dramatically over the period, alongside the more refined methods of economic and environmental assessment. Meanwhile, the network is almost complete and road-building remains out of fashion. Now that the profession has perfected its skills, its task may be almost done.

The 20% Vehicle

Colin Axon, Co-Deputy Director, James Martin Institute for Carbon and Energy Reduction in Transport and Department of Engineering Science

The hardest energy problem of all is reducing the carbon intensity of our transport system. Transport is overwhelmingly a single fuel system and therefore highly vulnerable, but fossil fuels just have so many advantages — they are cheap, ubiquitous, safe, reliable, and have a very high energy density. So much so, that we're really only looking for the second best solution. If, as a nation, we are to reach the overall 80% carbon reduction target, something dramatic is going to have to happen in the transport sector. If little were to change, then all of the carbon savings will have to be made in the residential and industrial sectors. Transport is the only sector that has continuously increasing emissions and energy demand — from 39.2 MtC[1] in 1990, to 43.4 MtC in 2005, accounting for over 25% of UK CO_2 output.

Looking ahead from our present position to the broad sunlit uplands of a low carbon economy, we find ourselves staring across a massive chasm with no credible bridges to get us there. Defining these bridges is the main aim and purpose of the newly formed James Martin Institute for Carbon and Energy Reduction in Transport (JMI-CERT). Our new group operates at the interface of the engineering and social sciences and will produce software tools to enable us to accurately estimate CO_2, energy, and financial indicators for various technical solutions for the reduction of greenhouse gases emitted by road transport. We will use these tools to propose various feasible scenarios which can advise in the choice of genuinely effective policy instruments. JMI-CERT is joint between the Department of Engineering Science and the Transport Studies Unit (TSU) in the School of Geography and Environment, and funded by the James Martin 21st Century School.

[1] Millions of tonnes of carbon (for CO_2 multiply by 44/12!)

Changes can be brought about by policy and fiscal instruments aimed at smoothing the pathway of implementation for low carbon technologies (perhaps as yet undeveloped). JMI-CERT aims to investigate the interactions of devices and policy in a "whole systems" modelling environment, operating within a system of feedback loops informed by data from real systems (on the road, where possible). The strength of this integrated approach is in exploiting the synergies between technologies, the supporting infrastructure, and the necessity of delivery to the consumer. Society is only at the beginning of developing low carbon vehicles and sustainable transport systems. Not only are there many important questions in fundamental engineering, but also "whole-system" questions which cannot be addressed by traditional means. Effective implementation of new engineering solutions can only be achieved when combined with integrated policy plans. A few small-scale programmes using novel power sources have had local impact, but large-scale deployment has proved too difficult from both engineering and policy viewpoints. Some promising technology has already been squeezed out of the market because the incentives and policy framework were not right. The removal of market barriers to the widespread take-up of lower energy solutions requires not only sustained technological improvements, but also expertly guided legislation and fiscal mechanisms.

There are a great many pundits and technology champions articulately professing what the future will be if their specific technology were taken up. They all promise that we could have equally cheap, but pollution free and environmentally sound mobility. The trouble is that currently no-one really understands how, in a practical engineering sense, to move the transport sector from high carbon usage to low carbon usage, across the chasm. The one thing which is clear is that technology on its own will not be sufficient — we (society) must change our attitudes and behaviour. A central feature of the JMI-CERT programme is to study the effects on markets and policy of using

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various new technologies to deliver practical low carbon solutions and pathways in the transport sector. The TSU recently completed a project for the Department for Transport on reducing CO_2 emissions from UK transport by 60% in 2030. This first step raised many questions requiring considerable long-term research on both technology and policy. There are currently four main types of feasible motive power sources, namely, electrical, fuel cell, hybrid, and high-efficiency IC engines — all at different stages of development and with diverse research, development, and deployment trajectories. The major element missing in the present research effort lies in the integration and inter-operability of these systems. The problems raised by the need to change to a low carbon transport system are very complex — the engineering and policy aspects are our focus. We have recently started work on three main areas, all of which are dependent on one another, in order to get a sense of the overall least cost and most effective combinations of technologies, together with possible implementation pathways:

1. Life Cycle Assessment (LCA) of alternative technologies in combination and the implications for carbon emissions and infrastructure. This will enable us to develop strategies for the transition from short-term (easy) winners to longer term "solutions". It is the optimal combination of the various technologies and policies to achieve the lowest practical carbon emissions, and a manageable technical switch of the supporting infrastructure, which we need to achieve quickly, in order to cut CO_2 soon, and so avoid entirely impractical cuts in 2050;
2. Understanding the detailed thermo-dynamic feasibility of these various energy systems and the efficiency of thermal and kinetic energy recovery. It is not possible to recover all waste energy, but the development of on-board systems to recover kinetic and low-grade thermal waste energies is an essential element of reducing CO_2 emissions;
3. Economic models of the technology options, travel demand, energy distribution networks and demand reduction methods. The effect of market mechanisms on technology development and consumer behaviour is a key question in all aspects of low-carbon energy sources. The role of electric cars in exploiting the electrical generation system, including hybrid "plug in" vehicles (not just electric plug-ins) has yet to be fully explored in meaningful detail.

Previous work has limitations such as considering carbon emissions only from new vehicles and not real data from the aging stock, or just looking at the raw financial costs of a technology, or only calculating the sustainability of a small element of a new technology (and then often not in the transport environment). The first attempt at a complete life cycle assessment for a fuel cell powered vehicle was only published in mid-2007, an analysis which the authors recognised had many weaknesses. There has been little previous work in looking at the so-called "embodied energy" of hybrid road vehicles. The current ones use a battery/motor system to give support to a conventional IC engine, but are such systems really a great step forward? Perhaps this is just an incremental advance, which won't lead us to a motive power source independent of oil. What would a truly radical "next generation" hybrid consist of? Should the vehicle be able to handle different fuels simultaneously, is it possible to get around the seemingly intractable hydrogen storage problem? What ratio of vehicle mass to fuel cell capacity might be optimal? What proportion of the vehicle power would be delivered by each component? There are an enormous number of combinations and variables — we suspect (expect?) the answer to be counter-intuitive.

The strategy is to find a good solution which will cut CO_2 emissions *soon*, rather than inch our way to a "best" solution in the indefinite future. This is important as CO_2 has a residence time in the atmosphere of 100–150 years, so it is more effective to implement the "nearly" solution early. The only thing which is clear is

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The 20% Vehicle cont.

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that the current technological pathways are not going to deliver the 80% reductions in CO_2 emissions by 2050. Perhaps the biggest question is understanding how the relative phasing of the transitions between different technologies, the costs and allied policy development could be arranged.

The key elements which must change, and the ones our programme will address, are the energy and power sources. Significant manufacturing developments are required so that economies of scale and lower costs for new low carbon technology can be achieved. These technical developments will emerge from the interface of electrical, mechanical, materials, electronic, information, and chemical engineering, and must be combined with the way they are used to enable the elimination of fossil fuels from the transport sector. Techniques such as dynamic life cycle assessment and exergy analysis can rigorously test combinations of technology, infrastructure, and their related policy options. There is a national need for costed technological alternatives, together with the necessary conditions for their implementation over time (e.g. the supporting energy distribution systems) and the policy measures needed to change patterns of consumption such as pricing measures and fiscal incentives. There is no sector-wide "road-map" which sets out how to achieve a lower carbon future for transport; we currently have a single fuel system and it is likely that the replacement will have similar structural characteristics. The big questions are what will it be, and how is society going to get there?

Obituaries

Rodney H Parsons, 1916–2009

Those in the Department from 1963 to the early 80s will certainly remember Rodney Parsons, the Department's first professional Administrator. The department had of course been "administered" before that, but until the Thom Building was completed in 1962, it had been very small, and the job was done part-time by one of the academics (e.g. Joe Todd in the 1950s). Rodney had been in the Royal Artillery throughout World War II, including Dunkirk, and later had a spell with the Arab Legion, of which he had many memories. His last military post had been as Officer Commanding the University Officer Training Corps, then based in Manor Road. On retirement from the Army, with the rank of Lt-Colonel, he joined the department as administrator in 1963, when Douglas Holder was the recently appointed Head of Department. The two complemented each other very well, and it is remembered that the department was a happy place under their joint leadership. He had a lively sense of humour, a very necessary quality for the job. He had also done a degree in Physics at Lincoln at some stage, which perhaps helped him to understand academics in general on the one hand, and engineers in particular on the other. There was quite a network of ex-service administrators and bursars in the Oxford of those days, which he must have found helpful.

The secretaries of the General Office were particularly fond of him, and if he was known for appointing those whose personalities and appearance were attractive, well, the males in the Department were hardly going to complain about that, and in most cases there was no doubt at all about the girls' competence to do the job.

One of his first tasks was to ensure that the visit of the Duke of Edinburgh to open the Thom Building, in November 1963, went off without a hitch. His military experience ensured that indeed it did!

He retired in 1984, by which time the Thom Building had changed from its rather sparse occupation of the early days, to bursting at the seams, and the Holder Building had been erected to relieve it a bit.

His wife Carol pre-deceased him, and Rodney moved from Chesterton, near Bicester, to Brightwell-cum-Sotwell, near Wallingford. He was devoted to his children and grandchildren, and rejoiced in their company. He died aged 93, on 16 June, having been very sprightly and alert right to the end. Indeed he had been shopping at Waitrose, and planting beans in his garden, on that very day. At a commemoration service for his life held in the village church on 15 July, his grandchildren devised a splendid collective tribute to him.

Andrew Reid

Andrew Reid, who died last May aged 78, read engineering at Trinity 1949–52, and went into the heating, ventilating and air-conditioning business, initially with GN Haden Ltd. In 1970 he founded his own firm, Andrew Reid and Partners, which specialised in "difficult" installations, often ones that had defeated their original designers. Some of his successes include the Guildhall School of Music, the Barbican Arts Centre, and more recently the Sainsbury Wing of the National Gallery, whose proper and reliable climate control is obviously vital for the preservation of paintings. His firm continues after his retirement, and can be read about on its website www.andrewreid.co.uk.

Andrew was also, from his youth, a keen sailor, and cruised widely.

A fuller obituary was in the Guardian on 27 May, drawn to our attention by Keith Cousins.

John C Thompson OBE

John Thompson, who died in September 2007, read engineering at New College from 1946 to 1948, having earlier done a "crash" services radio course at the Clarendon in 1941–2. In between he served as a Lt-Commander in the RNVR, specialising in radar, and receiving a Mention in Despatches.

After graduation he worked first in Joseph Lucas, and then in the Reed Paper Group, before joining a tungsten carbide manufacturing company in 1961, of which he became a Director. In 1976 he founded his own company to carry out the process of hot isostatic pressing, the use of very high pressure inert gas, and high temperatures, to make metal or ceramic components more dense, remove voids etc.

He retired in 1988 when his firm was taken over, but continued to work as a Business Counsellor. He lived in Kirtlington, a few miles north of Oxford, and often came to SOUE meetings. He died while on holiday in Cornwall.

Turbinia — Reflections on a Recent Visit

David Witt

In the 1880s and 90s in Newcastle, Charles Parsons was developing the multi-stage steam turbine into the enormously important power source that it has since become. There was some extremely clever engineering involved here, but this article is concerned with his development of the first turbine-driven boat, the *Turbinia*. She is 100 ft long, a mere 9 ft in beam, and contains turbines that were capable of 2000 HP between them, at speeds around 2000 rpm. (I deliberately use the Imperial units in terms of which Parsons must have thought — SI units will come later!) Turbines constituted a much more compact (and also vibration-free) source of power than the reciprocating steam engines that preceded them, and *Turbinia*'s recorded speed of over 34 knots made her the fastest ever water craft up to that time. Parsons had some serious problems getting the performance he expected, but eventually he succeeded, and then showed off his creation in 1897 by racing her at some 30 knots or more through the lines of ships assembled at the Spithead Review to celebrate Queen Victoria's Diamond Jubilee. *Turbinia*'s influence was substantial, and by 1907 the great transatlantic liners *Mauretania* and *Lusitania*, and the Navy's *Dreadnought* battleships were being driven by steam turbines of far greater power.

But by 1908, *Turbinia*'s pioneering mission was completed, and she was brought ashore and just left to rot. In 1926 her stern half with the turbines was taken down to the Science Museum in London. In the 1960s the two parts were welded together again and restored, and some 20–30 years ago I remember seeing her locked up in a shed in the Exhibition Park, Newcastle, visible only through the windows. But a year or so ago our immediate Past-President, Brian Cook, told me she was now on display in the Discovery Museum in central Newcastle, and I have recently taken an opportunity to go and see her. She has pride of place on the ground floor near the entrance (Figure 1) and is a most impressive sight. But the Museum is obviously aimed mainly at children, and since *Turbinia* neither moves nor makes a noise, nor can you get inside her, most of the young visitors seem to walk past without noticing her. Along one stretch of the after-hull, the steel plating has been replaced by transparent plastic, so you can see inside. This could usefully be extended, and you could see a lot better if there were some inside lighting. The internal space here is extremely congested with machinery, so you can see why they don't let casual visitors aboard. Maybe specialised pre-booked parties get a chance! There are some interesting displays alongside, particularly of some of the models he used when developing her hull shape, including one with a geared propeller driven by a twisted rubber band.

It was said earlier that Parsons had serious problems getting the performance he expected. He made a torque-meter and verified that the turbines could produce the predicted shaft power, so the fault was apparently with the propellers. So he made the first-ever cavitation tunnel to study them, and found that cavitation was indeed what he was getting. He eventually fitted nine propellers, three on each of three shafts (Figure 2), and this solved the problem.

The origin of the difficulty seems to have been that his turbines had no reduction gearing, perhaps because there was then no experience of making gearboxes to handle that power at that sort of speed. 2000 rpm was not a speed of which most Victorian engineers had any experience. Parsons himself later developed such gears for some subsequent vessels, and thereby solved the problem. Tests on *Turbinia* eventually showed that she did 32¾ knots (16.9 m/s), with the centre turbine and propeller shaft rotating at 2230 rpm (37.2 rev/s). Dividing one number by the other gives the propeller's "advance per revolution" as 0.454 m/rev. For efficient propeller design, the advance per revolution has to be not too different from the diameter, and in fact the nine propellers eventually fitted have a diameter of 18 inches (0.457 m), almost exactly the same. The area of a disc of that diameter is 0.164 m^2, and the total area of the three blades somewhat less, maybe 0.1 m^2.

But the force needed to propel *Turbinia* at this speed was probably around 50 kN. To get this force from one such propeller would thus need a pressure difference across the blades of at least 500 kPa. It is now known that more than half of this pressure difference arises from a pressure *reduction* on the front face. But the total static pressure in the water only a metre or so below the surface is little above the atmospheric, 100 kPa. So using only one such propeller relies on a very large negative absolute pressure! Even with three of them it is still pretty marginal. Geared-down turbines would have permitted bigger propellers, for which there was certainly room (Figure 2). But by using nine small ones, the pressure difference across the blades will come down to something like 60 kPa, and there begins to be some hope. He had already got his turbines to work by dividing the pressure drop from boiler to condenser into lots of little drops across many successive turbine wheels, and presumably realised he had to do the same thing with his propellers.

It is splendid that this remarkable vessel is now on public display, and indeed has been since 1995. Go and see her if you get a chance.

Figure 1: *Turbinia*

Figure 2: *Turbinia*'s array of propellers

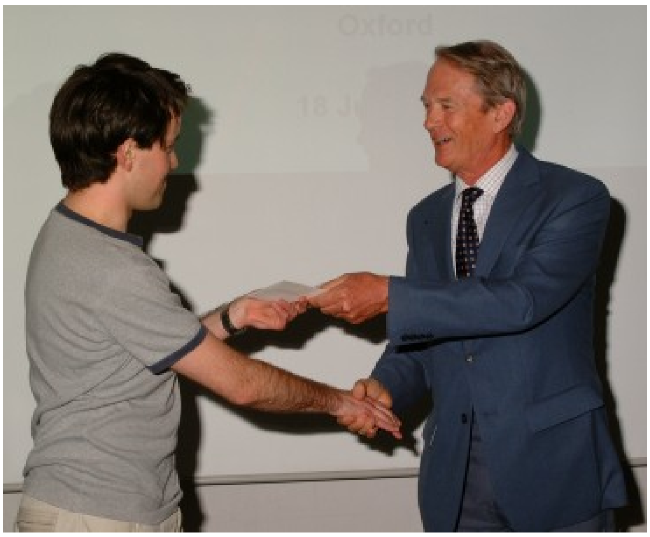
Project Exhibition 2009

David Witt

The exhibition attracted 19 entries this year, a bit more than last year's 15, but well below the 24 and 29 of the two previous years. But there was also less money to give away in prizes, since one of our regular sponsors has been feeling the effect of the recession, and another seems to have lost interest in Oxford! But Atkins and GlaxoSmithKline both contributed as in the past, and we are very grateful to them.

The judges awarded a £500 prize for best exhibit to Ken Chatfield for "Visual Search by Shape", an investigation into whether one could devise a program that would do for shapes what Google does for text. It is perhaps not surprising that without Google's resources he hadn't got as far as they have, but he was certainly able to demonstrate a start in that direction.

The £500 Atkins prize for the best exhibit in the civil/structural engineering field went to Lawrence Walton for a study of how to design footbridges so that they don't suffer from the crowd-driven vibration that plagued London's Millennium Bridge when it was first opened, and the pedestrians brought their walking into synchronism with the lateral motion of the bridge.



Lawrence Walton receiving the Atkins prize

To compensate for this year's reduction in sponsorship, SOUE contributed a £200 prize for an electronic exhibit, and the judges awarded this to Gareth Lott for an "Optical Wireless Link Tracking System".

£100 prizes went to Ben Sitler for "Vertical and Horizontal Loading of Grillage Foundations"; to Rachel Swidenbank for "Computational Analysis of a Transverse Horizontal-axis Water Turbine", of the type intended to get power from the tides; and to a three-man group of Yuan Gao, Osman Darr and Edward Wang for "Sustainable 'Unplugged' House in the Shetlands", with some electrical hardware that could contribute to its self-sufficiency.

And four £50 prizes went to Nathan Ewin, David Howie, George Lederman and Zun Wang.

There were several other interesting exhibits that did not win prizes, for instance, to mention only two, Samuel Johnson's "A Better Kettle" and Christopher Wood's practical study about reinforcing masonry or adobe structures with plastic mesh so that they were less likely to collapse on to their occupants in an earthquake.

The hard-working judges, to whom we are as ever very grateful, were this year:

Richard Ashton, Balliol 1995–9, now with BAE Systems

Mike Ford, St Edmund Hall 2000–4, now with Arup

Amelia Gould, Somerville 1996–2000, now with Actica

Paul Jones, Brasenose 1996–2000.

Finals and Prelims Prizes Awarded 2008

The Examiners recommended the following awards in respect of Final Honour Schools in 2008 (these were not available at the time of publication last year):

Engineering Science Part 2

Maurice Lubbock Prize for best performance:

Peter M Kennedy, Magdalen

Edgell Sheppee Prize for excellent performance:

David R Ellis, St John's

ICE Prize for best performance in civil engineering:

Stuart M Hookham, Oriel

IMechE nomination to the Frederic Barnes Waldron Prize:

Stuart R Abercrombie, Hertford

IMechE Best Student Certificate

Vicki Barker, Christ Church

IET Prize for outstanding academic achievement:

Ashley A Napier, Lincoln

IET Manufacturing Engineering Prize:

Jonathan P Taylor, St Edmund Hall

IChemE Prize for best performance in chemical engineering:

Oliver Cates, St Hugh's

Lonza Biologics Prize for the best final-year performance in chemical engineering:

Ben Jones, St Catherine's

Cornhill Prize for best performance in biomedical engineering:

James R Grice, University

Babtie Prize for the best project in civil engineering:

Alan J Carter, St Hugh's

IMechE Prize for the best project in mechanical engineering:

Alexander G Philipps, Christ Church

IMechE Certificate for an outstanding project in mechanical engineering:

Bola Ogidan, Christ Church

Motz Prize for best project in electrical engineering:

Adrien J Geiger, Somerville

Ronald Victor Janson Prize for best project in electronic communications:

David R Ellis, St John's

Worshipful Company of Scientific Instrument Makers Project Prize:

Johannes Buerger, Lincoln

HMGCC Project Prize in information engineering:

Elizabeth S Bush, Wadham

The Cornhill Prize for an outstanding project in biomedical engineering:

David P Steynor, University

Royal Academy of Engineering Prize for excellent design in a fourth-year project:

Peter M Kennedy, Magdalen

Rolls-Royce prize for an outstanding project displaying innovation:

Christopher J Hambidge, St John's

Engineering Economics and Management, Part 2

Maurice Lubbock Prize for best performance:

Madeleine C Taylor, New College

Edgell Sheppee prize for best performance in an engineering project:

Hannah L Kershaw, Keble

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Finals and Prelims Prizes Awarded 2008 cont.

(Continued from page 25)

Pilkington Prize for best performance in a management project:

Prasanna Kannan, Christ Church

Engineering and Computer Science, Part 2

Maurice Lubbock Prize for best performance:

Octave Oppetit, Exeter

Engineering Science, EEM and ECS Part 1

Edgell Sheppee prize for laboratory or drawing office work:

Matthew C Collins, Hertford

Gibbs Prize for best Part 1 project, jointly to:

Philip A Kelly, Balliol; Celia Y Robson, Keble; Rachel L Swidenbank, St John's; Keong H Yeoh, Brasenose

Royal Academy of Engineering Prize for best treatment of sustainability in a project, jointly to:

Emily L Ball, Exeter; Sean Boyle, Lincoln; Oliver C Gingell, St Edmund Hall; David I Henderson, St John's; Daniel T Whitehouse, University; Irina Yanshina, New College

Biomedical Engineering MSc

Cornhill Prize for best performance:

Michael B Molinari, Wolfson

Cornhill Prize for an outstanding individual project:

Lauriane E Sermet, Wolfson

The Moderators recommended the following awards in respect of the Preliminary Examination:

Crown Packaging UK plc Prize for best performance:

Ka Ho Lau, Balliol

Shell prizes for outstanding performance:

Ye Chen, New College; James K McNiven Young, New College

Finals and Prelims Prizes Awarded 2009

The Examiners recommended the following awards in respect of Final Honour Schools in 2009:

Engineering Science Part 2

Maurice Lubbock Prize for best performance:

David P Hayden, Oriel

Edgell Sheppee Prize for excellent performance:

David Bishop, New College

ICE Prize for best performance in civil engineering:

Nicholas P Milburn, Pembroke

IMechE nomination to the Frederic Barnes Waldron Prize:

Matthew CJ Collins, Hertford

IMechE Best Student Certificate

Robert Kiwanuka, Christ Church

IET Prize for outstanding academic achievement:

Nassia Inglessis, St Edmund Hall

IET Manufacturing Engineering Prize:

Henry T Luckhoo, Trinity

IChemE Prize for best performance in chemical engineering:

Simon PJ Oakes, St Hugh's

Lonza Biologics Prize for the best final-year performance in chemical engineering:

Alexander Burtenshaw, St Catherine's

Cornhill Prize for best performance in biomedical engineering:

Natalie Hockham, St John's

Babtie Prize for the best project in civil engineering:

Divindy A Grant, Oriel

IMechE Prize for the best project in mechanical engineering:

Saraansh Dave, St Anne's

IMechE Certificate for an outstanding project in mechanical engineering:

Paul Gee, Wadham

Motz Prize for best project in electrical engineering:

Timothy Hertz, New College

Ronald Victor Janson Prize for best project in electronic communications:

Christopher W Chan, St Catherine's

Rohde & Schwarz Prize for best project in high-frequency test and measurement

Benjamin D Cox, Exeter

Worshipful Company of Scientific Instrument Makers Project Prize:

David I Henderson, St John's

HMGCC Project Prize in information engineering:

Ashley R Wharton, St Catherine's

The Cornhill Prize for an outstanding project in biomedical engineering:

Victoria M Sanchez, Wadham

Rolls-Royce prize for an outstanding project displaying innovation:

Ken Chatfield, Oriel

Engineering Economics and Management, Part 2

Maurice Lubbock Prize for best performance:

Leo L Masson, St Catherine's

Edgell Sheppee prize for best performance in an engineering project:

Zun Wang, St Anne's

Engineering and Computer Science, Part 2

Maurice Lubbock Prize for best performance:

John FJ Mellor, Balliol

Engineering Science, EEM and ECS Part 1

Edgell Sheppee prize for laboratory or drawing office work:

Daniel TB Slowe, New College

Gibbs Prize for best Part 1 project, jointly to:

Nathan Bennett, Keble; Alexander Duncan, Worcester; Ian C Horn, Christ Church; Sam Rudgard, Exeter

The Moderators recommended the following awards in respect of the Preliminary Examination:

Crown Packaging UK plc Prize for best performance:

Muhammad Faizan Ahmad, Pembroke

Shell prizes for outstanding performance:

Joseph Camm, Exeter; Jyi Sheuan Ten, University

Professor Alexander Thom and Megalithic Astronomy: A Revival of Interest

David Witt

Professor Thom was Head of the Department of Engineering Science from 1944 to 1961. His engineering career had been in aeronautics and aerodynamics, but he was a man of great versatility and practical skills, and from the 1930s onward he developed a passionate curiosity about the arrays of standing stones, mostly in Scotland and the North of England, but also the much more studied ones of Stonehenge and Avebury. He attributed the origin of this interest to a visit to the stones of Calanais (Callanish) in 1933, when cruising his yacht in the Hebrides. The Pole star being visible, he spotted that some stones defined an avenue aligned almost north-south. But when the stones had been erected, several thousand years earlier, the Pole star had been in a quite different place, as a result of the "precession of the equinoxes". So how did the builders establish which way was north?

Over subsequent years, and particularly in retirement, he surveyed hundreds of these arrays, mostly either circles or egg-shaped rings, but sometimes more subtle arrangements. From statistical analysis of his measurements, he concluded that they had been erected by people who used a linear measurement unit of 0.829 m (2.72 ft), and that they preferred to lay things out using, wherever possible, integral numbers of this unit. He termed this unit the "megalithic yard", and concluded that multiples and sub-multiples of it were also used for various purposes.

He believed that many of these stone arrays had been erected for astronomical purposes, and looked for specific instances of this. Observation of the azimuth of the rising or setting sun seemed to have been used to determine the dates of solstices and equinoxes, and hence define a calendar, of obvious use to a farming community. But the inhabitants of Northern Scotland were a sea-faring community too, and therefore much interested in tides and tidal currents, which depend on the moon. This alone would justify study of the moon, but there was the added incentive that in northern latitudes with wide horizons and no outdoor artificial lighting, the rather odd motions of the moon would have been much more noticeable than they are to modern city-dwellers, so might inspire study for its own sake. A desire to predict eclipses might have been part of it too. Thom claimed that at numerous sites there were "alignments" between standing stones and prominent features on the skyline, to indicate the extreme positions at which the moon rose or set. They don't indicate them now, because of astronomical changes in the intervening 3500–4000 years, particularly in the angle between the Earth's equatorial plane and the plane of its orbit round the Sun, now about 23.4°, but then about half a degree more. This can sometimes mean that a modern observer would have to stand hundreds of metres from where the megalithic observer would, in order to see the same thing. So Thom had to do extensive calculations to make his case.

An attempt to predict eclipses would, Thom thought, have required years of observations and some quite advanced "calculations" on the part of his Megalithic observers. These are explained in one of his books, *Megalithic Lunar Observatories*[1], and would have involved two levels of interpolation between daily records of setting or rising azimuth, effectively "samples" of a continuous process. There are some curious fan-shaped arrays of stones in Caithness, which Thom suggested may have been effectively "slide rules" to do these calculations. And only every nine years could one make meaningful observations! But they did have several hundred years to do it, if, as Thom assumed, there was a "caste" of people devoted to the task. Julius Caesar recorded of the Celts in about 50 BC that their Druids enrolled young men for 20-year courses in which they learnt much about the heavenly bodies (and much else), but committed it all to memory rather than wrote it down. But that was quite a different race of people, who came on the scene much later.

[1] Clarendon Press, 1971

Thom never claimed to be an archaeologist, but when he published his findings[2], the archaeologists obviously had to take note, though most of them were not equipped to understand or criticise Thom's mathematics. Initial reaction seems to have been of great interest and admiration, but gradually scepticism grew. Thom's work seemed to imply a much higher level of sophistication on the part of these early people than was consistent with previous research results. To which it could be replied that if they could erect these enormous stones, build seaworthy boats and navigate the treacherous seas around Northern Scotland, then they were no fools, and the size of their brains was the same as ours. But unlike the ancient civilisations around the Mediterranean, no written records survive, even if they ever had any. But those whose culture does not include a written language develop their brains in other ways. The early bards of around 800 BC who preserved the Homeric sagas, *Iliad* and *Odyssey* (24 books in each!), did so purely by memorising them.

Some who extended or repeated Thom's work have concluded e.g.:

a) that the use of the megalithic yard was certainly not universal — some areas show no trace of it;

b) that Thom's choice of astronomic "alignments" was over-selective[3]. If you choose this stone and that cleft on the horizon, then they seem to indicate a relevant direction. But that stone and that other cleft indicate nothing at all. Perhaps the pair you chose was just a random occurrence.

To me it does seem that Thom may have occasionally claimed that a conclusion was established beyond doubt, when it might have been safer to say "it does look very much as if ...". He clearly felt an empathy with the people whose work he was studying, as if he could instinctively see what they were aiming at. Others from different backgrounds might fail to see it at all.

More recently various people have been trying to re-assert the significance of Thom's findings. Edmund Sixsmith, an ex-Cambridge civil engineer, is one of them, with whom I have been in recent correspondence. He has just published an article on Thom in the statistical magazine *Significance*[4], and has another on the way. He claims that Thom "has been airbrushed from accepted wisdom". A work published in 2007 was Robin Heath's *Alexander Thom — Cracking the Stone Age Code*. The author's background, like Thom's, is technical rather than archaeological, and I think his book is not entirely error-free (is any?) but the one that most irritated *me*, his mis-spelling of Barnes Wallis' surname, is irrelevant to the larger question. A lot of work has clearly gone into it. He gives a good account both of Thom's work and of the subsequent controversy. Thom's views are now apparently highly unfashionable among professional archaeologists — if you believe them you are most unlikely to get promoted, rather like a biologist who suggests that acquired characteristics can perhaps be inherited by the next generation, or that someone designed us.

But others have tried to link the stone-circle erectors and their megalithic yard to all sorts of curious speculations about the past, varying from the just believable to the highly unlikely[5]. One that I myself find extremely unlikely is the suggestion that the megalithic yard was defined in terms of the length of a pendulum that had a specified periodic time. For a start, the period of a pendulum depends on how its mass is distributed (point masses on the end of light rods are more appropriate to A-Level questions than to the real world); and then, how did they measure the periodic time to adequate precision?

Units similar to the megalithic yard do seem to have been used in other places, and there are some tantalising possible links to some other

(Continued on page 30)

[2] e.g. in Megalithic Sites in Britain, 1967

[3] Ruggles CLN, Astronomy in Prehistoric Britain and Ireland, 1999

[4] Sixsmith E, The megalithic story of Professor Alexander Thom, Significance, March 2009

[5] e.g. Knight C & Butler A, Civilisation One, 2004

Professor Alexander Thom and Megalithic Astronomy: A Revival of Interest cont.

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units. For instance, you could define a litre as the volume enclosed by a cube of side 0.1 m. A cube of side 0.1 megalithic yard has a volume quite close to one English pint! But who first defined the pint, and when? And there is that curious unit, the "perch", which pupils once had to learn about in school, but probably not these last 50 years. A linear perch is 5.5 Imperial yards, and a "square perch" (5.5 × 5.5 yards) is a 160th part of an acre, and was much used in land measurement until quite recently. But why ever would anyone define one unit as being 5.5 times the length of another one? But if you replace imperial yards by megalithic yards, the ratio is quite close to six. Did someone in the distant past redefine the yard, but leave the perch the same, so as not to upset the farmers and landowners?

Thom seems to have left a fascinating controversy behind him. If anyone cares to grab a battle-axe and join in, they might have an interesting time.

The standing stones of Calanais on the Isle of Lewis that inspired Professor Thom 76 years ago (photograph by Sarah Witt)

The Institute of Biomedical Engineering

The Institute of Biomedical Engineering (located at the Old Road Campus on the Churchill Hospital site)

A Hydrogen Car

A prototype car driven by a hydrogen fuel cell has been in the news recently, and has some Oxford connections. The designer is Hugo Spowers, who read engineering at Oriel, 1978–81, and the wheel motors owe a lot to Malcolm McCulloch, tutor at Christ Church.

Cranfield, where the designer studied automotive engineering, has also been involved, and Sebastian Piech, a descendant of the designer of the Porsche, is funding its further development.

The two-seater body is made from recyclable composites, and the car weighs only 350 kg. The fuel cell drives the vehicle through four motors, one in each wheel, and the electronics is configured so that they can regenerate when braking. The maximum speed is said to be 50 mph, adequate for the "urban car" that it is intended to be. If the hydrogen is derived from natural gas, this implies some CO_2 emissions at the source, but only about 31 g/km, far less than for any petrol-engined car in production. Eventually hydrogen may be produced economically from some greener CO_2-less source. The actual fuel energy consumed in propelling the car is claimed to be equivalent to that of a petrol-engined one doing 300 miles per gallon. The electric motors are said to have three times the power/weight (or possibly torque/weight) ratio of conventional motors. This is attributed to the use of a "new material", but they don't say what!

It is proposed not to sell the vehicle, but to lease it for around £200 per month, which would include maintenance and the cost of the hydrogen. The first fleet might be established in Oxford or some city of similar size.

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