

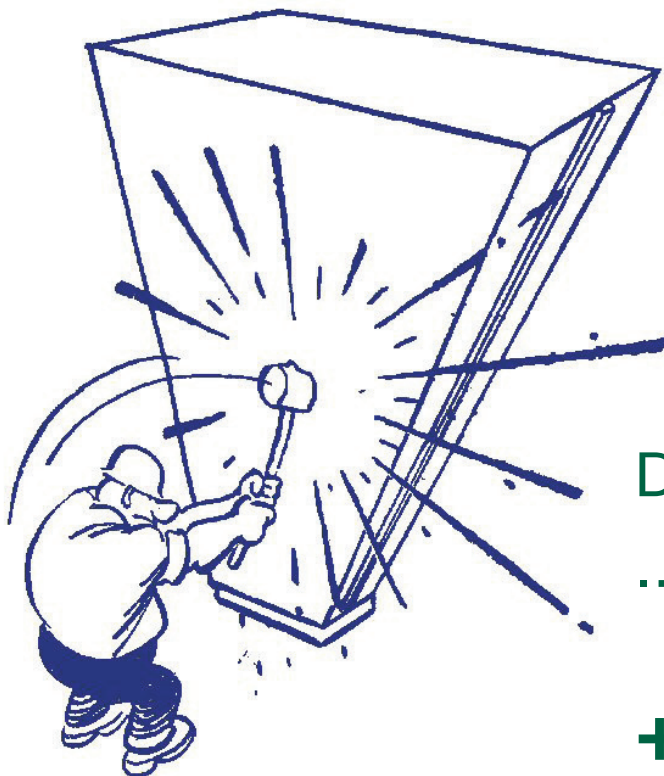
The Wolfson Centre for Bulk Solids Handling Technology



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The Wolfson Centre is recognised as a leader in the field of powder and bulk solids handling technology and has established strong links with industry. This enables the Centre's experts to offer a unique range of consultancy services, research projects and short courses.

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Don't pick up a hammer,
.....pick up the phone!

+44 20 8331 8646

Providing cost-effective solutions to industrial problems

Our mission

...is simply to help industry to get its powders and bulk materials to behave in the way they need them to!

Our philosophy

Our key to achieving this is to measure a material's behaviour in a relevant setting, then use that information in a sound process model to design or select the right solution.

The same techniques can also be used to help in reformulating materials you make, so they behave better in your own, or your customers', plants.

Resources

We have the greatest collection of resources to tackle solids handling challenges under one roof, anywhere in Europe – possibly in the world!

The expertise of our people – our consulting engineers have between them well over a hundred man-years of experience in solving problems in the flow and processing of powders, granules and lump materials, in all industries from pharmaceuticals and food to mining and chemicals or renewable energy and recycling. Our research team concentrate on nothing else but the needs of industry – and are at your disposal.

Pilot plant – our industrial-scale plant is available for your project, including pneumatic and mechanical conveying, hoppers and silos, screening, blending, feeding, dosing, pressing, transport, environmental effects, control systems and all that you find in a real plant or logistics chain.

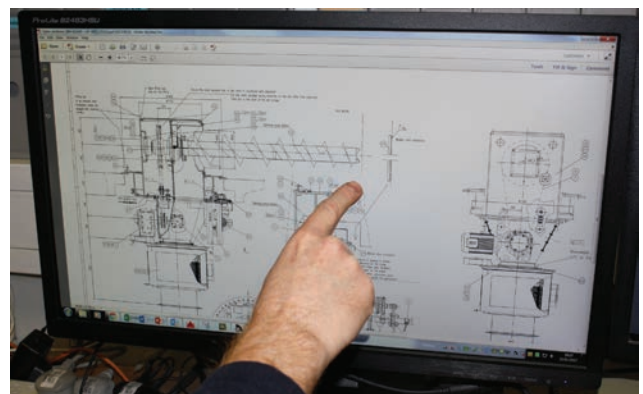
Material characterisation – we can measure every behavioural aspect of a powder or bulk material; our comprehensive facilities employ not only standard techniques but also all the latest methods of putting numbers to the behaviour of powders and bulk materials.

We can use these measurements in our proven process models to predict what will happen to the material in your existing / proposed plant or logistics chain, or to select the right solution. Many of the tests and models have been developed here at the Wolfson Centre and are available nowhere else in the world.

Challenge us!

Don't struggle on by yourself. Phone us with your solids handling challenge. There is a 95 % chance our engineers have seen the same problem on other plants, or with the same or similar materials elsewhere. Even if we haven't, we have the experience to find the right path to the solution you need:

- **Telephone assistance** – a short chat (free of charge) to point you in the right direction
- **Day visits** – to offer advice, or to audit your operations for improvement
- **Troubleshooting** – recommending changes, redesigns, material reformulations, etc.
- **Material characterisation and assessment** – on a contract or one-off basis
- **System/equipment selection and design** – to arrive at the best designs or components
- **Technology transfer** – so you can meet the challenges yourselves (funding may be available)
- **Equipment development** – for your novel idea or unique solids processing requirement
- **Research** – If you need to understand your materials and processes in more depth
- **Short courses** – both here at the Wolfson Centre and at your own premises
- **Expert witness services** – reports, analyses, 'forensic engineering' and court appearances
- **Process modelling** – to predict what will happen to the material in your existing or proposed plant or logistics chain, and to select the right solution
- **Pilot plant trials** – test the materials or proposed system off-line to avoid problems on start-up.



Impartial and independent evaluation of equipment design can be provided

Consultancy services

The Wolfson Centre undertakes consultancy services in industry in the fields of:

- **Hoppers and silos**
- **Pneumatic conveying**
- **Characterisation**
- **Product feeders**
- **Product quality (segregation, attrition, caking)**
- **Environmental and transport effects**
- **Dosing and dispensing**
- **Abrasion and wear**
- **Overall system design and integration**
- **Sampling**
- **Dust prevention and control**
- **Packaging**
- **Processing of powders and bulk solids**
- **Expert witness services**

Hoppers and silos

Hoppers, bins and bunkers are widely used in industry for storing bulk materials. Such materials can range from fine to very coarse materials in quantities ranging from a few kilos to many thousands of tonnes. The information that is often used by designers or end users can be very sparse indeed when it comes to providing genuinely useful insight into the bulk materials storage and flow behaviour. In many cases materials that could be considered benign by first inspection transpire to have very problematic behaviour such as:

- Discharge reliability issues (often made worse by extended static storage periods)
- Segregation
- Poor drain down efficiency
- Agglomeration / cross-contamination

In many instances these types of problems are a result of an interaction between the bulk properties of the materials to be handled and the design or operation of the storage equipment.

The range of industries whose efficiency and profitability is affected by flow problems is vast. Such plants can range from import terminals, power generation, food processing, pharmaceuticals and just about any other process based plant you might care to name!

By measuring the flow properties of the material to be stored, the Wolfson Centre can determine the hopper angle, outlet size and internal finish needed to ensure the vessels discharge without trouble.

Through the use of various characterisation tests, it is possible to design, and re-design, hoppers and silos for consistent, reliable flow. Reliable discharge will ensure that process plant can be operated with the minimum of down time caused by materials handling problems.

Structural design can also be a challenge for large silos. We have the knowledge and understanding to undertake prediction of loads on silo structures.



Projects relating to silo operational problems are commonly undertaken

Pneumatic conveying

Pneumatic conveying is a commonly used means of transporting bulk solids. Applications range from unloaders for large-scale ship bulk cargo through to small in-plant systems. The Wolfson Centre has wide experience of all of these systems and of solving the problems that can arise as a result of mismatching materials, feeders, pipeline designs or air movers with each other.

Facilities in our laboratories include:

- Pipelines in a range of industrial sizes, with a large number of layouts available for system simulation, with both dense and lean phase flow conditions
- Fully instrumented pipe loops for measuring the performance of conveyed products
- Data gathering and processing systems for analysing the conveying behaviour of products tested and for prediction of performance of proposed systems
- Rotary valves, top and bottom discharge blow tanks, venturi feeders and suction nozzles for feeding negative and positive pressure conveying systems.

Characterisation

Characterisation of bulk solids can require the application of different techniques depending upon the context of a given client requirement. A key aspect to much of the work undertaken is that the bulk scale of scrutiny (i.e. the interaction between many particles, as opposed to individual particle properties) relates to industrial or standardised conditions. The former may consider the influence of temperature or moisture variations on bulk behaviour, whilst the latter allows direct comparison and benchmarking to previously obtained test data. The bulk behaviour of interest could relate to moisture uptake, agglomeration, degradation or blend stability. Usually associated with such studies are measurements of particle size distribution using sieves or laser diffraction (with either wet or dry analyses) which are often supported by SEMs of the particles which serve to illustrate the morphology and general nature. Analysis of particle shape can also be supported through the use of a 2D optical approach using a recently acquired Malvern Morphologi.

Product feeders

Many industrial processes require that a product is discharged from a storage bin or hopper at a controlled rate. Often the flow of material has to be 'throttled' to enable a steady flow rate from the attached feeder. The delivery of material to the feeder from the hopper must also take place in a controlled and steady manner, which in itself is achieved by correct discharge section design. Both of these aspects are interdependent and need to be addressed as a single requirement at the design stage if trouble-free operation is to be achieved. Feeders should only be selected for a system once the hopper has been properly designed so as to prevent arching and rat holing, and to support the maximum discharge rate required (see 'Hoppers and silos' on page 3).

Product quality: environmental and transport effects, segregation, degradation and caking

Throughout industry, the maintenance or improvement of product quality is directly linked to both market perception of a brand and, by implication, its profitability. Various factors can be present with a process that can have a direct bearing upon the qualities of a material. The Wolfson Centre has world-leading expertise in a wide range of issues related to product quality, the most common of which include particle degradation, caking and segregation in handling, transport and storage. This includes test techniques and process models, which are also available for purchase.

Dosing and dispensing

Often in pharmaceutical and food industries, materials have to be dispensed in small, closely controlled quantities, sometimes at high speed. The Wolfson Centre has special expertise in developing and troubleshooting systems for this purpose.



Evaluation of segregation behaviour (surface or air effect) can be undertaken using unique testing equipment

Abrasion and wear

Many handling systems suffer from wear, causing expensive component replacement and much more expensive plant downtime. The Wolfson Centre has developed the latest and most cost-effective test machines for evaluating product erosiveness/abrasiveness and models for predicting plant life, as well as maintaining leading expertise in materials selection for wear protection.

Overall system design and integration

To get a complete processing system to work properly in balance requires that the elements are all interfaced to each other correctly, and any unwanted interactions contained, as well as each being capable in their own right. The Wolfson Centre has long experience of troubleshooting system integration problems, and undertaking overall system design projects to ensure smooth start-up of new plants, minimising over-run of cost and time and maximising performance from an early stage.

Sampling

Many industrial issues relating to poor performance of bulk handling equipment can be traced back to a design or specification that has been based upon incorrect samples of the bulk solid being obtained and used as the basis of decision making in the early stages of a project. It is important to understand the segregation behaviour of a bulk solids in the context of the point in the process where samples are obtained will have an extremely strong influence over the quality/validity of such samples. In this respect an independent review of the adequacy of sampling points for access and the suitability of methods to extract samples can serve to considerably reduce the risks induced into projects.

Dust prevention and control

Ineffective dust and powder control in the workplace can cause problems. Airborne particles are a major cause for concern, particularly since the introduction of increasingly stringent environmental legislation. Any company that has (or is in the process of gaining) BS 7750, or that regularly undertakes a COSHH assessment, will understand the need to monitor and control airborne particles.

Our consultants are available to advise on a number of topics, including control techniques, on-site dust surveys, product degradation, material characterisation, dust generation, product segregation, explosion protection, design of new systems or modifications to existing systems and cost analysis of options, assessment of vendors' bids, and troubleshooting on site (from one-day visits to

larger investigative projects). They are also available to undertake research into new technology and testing of special equipment.

Packaging

Apart from its expertise in controlling the rate and accuracy of filling the Wolfson Centre also has the expertise to evaluate the relationship between packaging, the environment to which it is exposed and the effects on the material contained. Many bulk particulate materials are processed and loaded into 'packages' of various types. Such packages can range in size from 1m³ (a big bag) to 10g medicinal sachets or 10mg doses in inhaled drug dispensers.

Processing of powders and bulk solids

Many processing steps include the movement of particulates and their interaction with each other and the processing conditions.

The expertise at the Wolfson Centre is often brought to bear on analysing, improving or redesigning processes as diverse as:

- Blending
- Drying
- Granulation
- Pressing
- Pyrolysis and gasification
- Separation
- Size reduction.

Expert witness services

For companies involved in litigation, arbitration or adjudication matters, the Wolfson Centre can provide reports, analyses, 'forensic engineering' or court appearances.

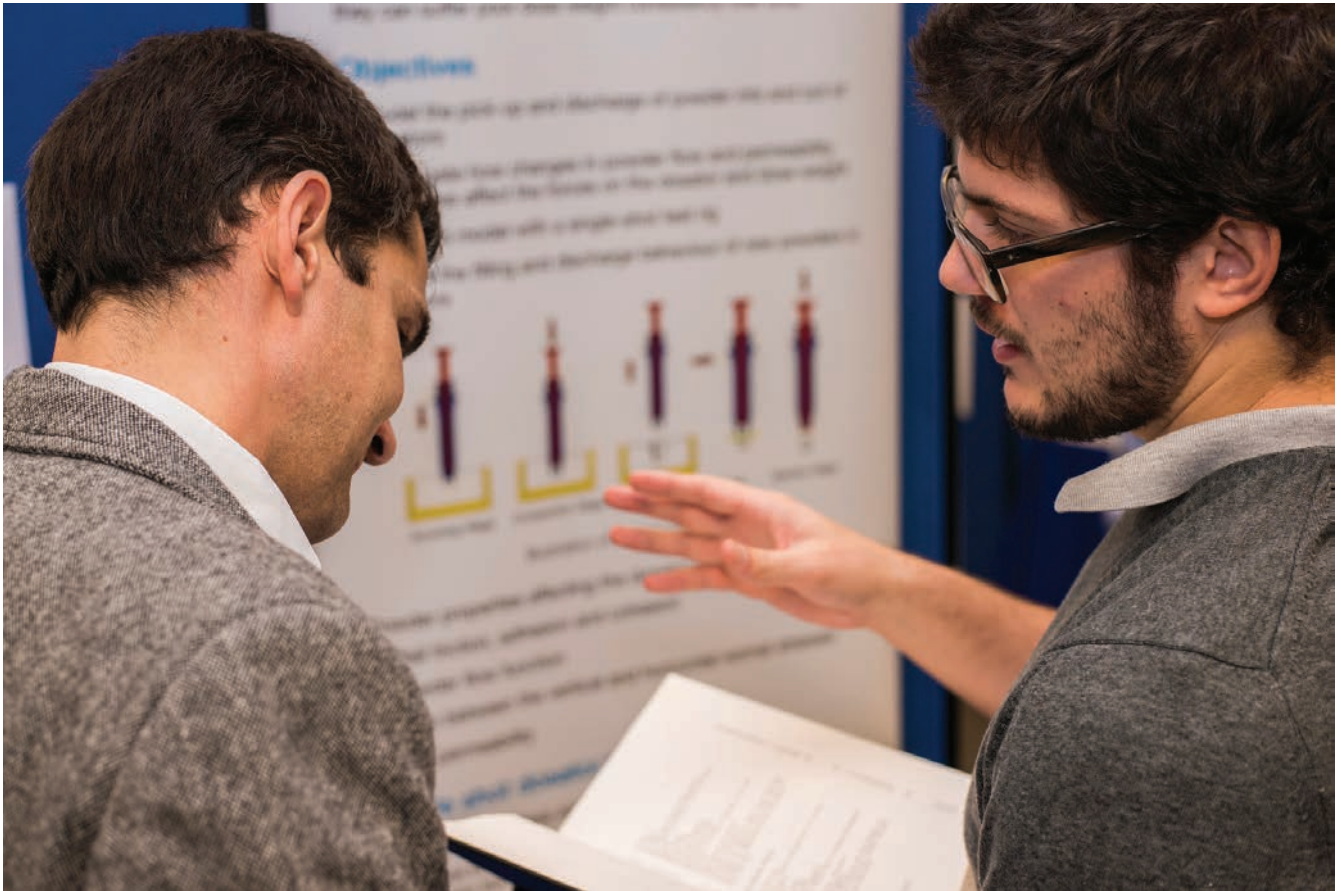
Links with industry

The Wolfson Centre has very strong links with industry through its consultancy activities, and this often leads to industry becoming involved in other areas such as research, Knowledge Transfer Partnerships and short courses. In addition, the Wolfson Centre is closely engaged with trade and professional bodies including the Solids Handling and Processing Association (SHAPA), Materials Handling Engineers Association (MHEA) and the Institution of Mechanical Engineers (IMechE).



Research into punctured bends form part of our analysis work

Research and Knowledge Transfer



Research is an important aspect of the work undertaken by the Wolfson Centre, which employs research fellows and students studying to MPhil and PhD level, all constantly seeking novel methods of bulk solids characterisation, of designing bespoke handling equipment and improving process models.

Their research is aimed at addressing real problems within industry including pharmaceutical, food manufacture, minerals, aggregates, chemicals, metals, biomass/renewable energy, recycling, household goods to name but a few. Their understanding of the behaviour of powders and particulates is continually increasing, allowing us to help solve even more of the problems found in many industries that handle and process materials in bulk particulate form.

To allow the staff and researchers to continue their work, the Wolfson Centre is very fortunate to receive various grants, either direct from industry to concentrate on a specific area for a specific company, or from one of the Research councils to aid in more fundamental research. All the projects undertaken are of direct relevance to problems encountered in industry and the knowledge gained from these is disseminated in the form of technical papers or as presentations at conferences. Much of our research that is directly funded by industrial clients is confidential in nature and restricted in terms of what can be published. Often this covers new manufacturing processes, new materials and improvements to processing techniques.

Non confidential information derived from these projects is also applied during the delivery of consultancy work and incorporated into the series of short courses run by the Wolfson Centre.

A purpose-built laboratory and pilot plant complex at Chatham Maritime houses the equipment for research projects and provides the facilities to enable researchers to design and produce their own pieces of equipment with the help of the on-site technicians.

Some of our current research projects include:

Virtual Formulation Laboratory (VFL), a software tool for prediction and optimisation of manufacturability and stability of advanced solids-based formulations. Project undertaken as part of a consortium involving 3 other Universities around the UK, funded through the EPSRC.

Predicting degradation of bulk solids during pneumatic conveying. Project funded by Industry.
PhD student: Ben Kotzur B.A.Kotzur@gre.ac.uk

Conveying of Wet Ores. Project funded by Industry.
PhD student: Martin Chisholm m.chisholm@gre.ac.uk

Development of a methodology for evaluating dust mobility and concentrations during biomass handling operations to inform on specification of explosion counter measures. Project part funded by Industry.
PhD student: Lahiru Lulbadda Waduge
L.L.LulbaddaWaduge@gre.ac.uk

Developing a novel technology for pneumatic conveying systems control. Project part funded by industry.
PhD student: Amit Kumar amit.kumar@gre.ac.uk

Powder Flow Technology (PFT) software development and investigation of the particle to bulk scale measurements.
PhD student: Vivek Garg v.garg@gre.ac.uk

Prediction of the synergistic effects of degradation and segregation in handling and storage of wood pellets for power generation. Project part funded by BF2RA.
PhD student: (Jeff) Susantha Dissanayake
S.C.Dissanayake@gre.ac.uk

Technological Aspects of Bulk Particulates in the Industrial Context - Development of a Wood Pellet Reception and Storage System "Grading Tool". Project funded by the UK Pellet Council.
PhD student: Gulab Singh g.singh@gre.ac.uk

Blade compressor Trials; Phase 2 of a project funded through the Horizon 2020 scheme, in collaboration with the manufacturers of this novel piece of engineering, initially looking at it's application to pneumatic conveying systems but with the long term aim to apply the technology further afield in industry.

Investigation of wear in industrial coal grinding and drying plants; a collaboration project involving another UK University and one of the largest steel producing companies in Europe.

Filter rig

The filtration of particles from air flows (whether in pneumatic conveying systems or environmental air) is of increasing importance to many industrial sectors from a Health & Safety and operational cost perspectives. In order to support industry in optimising its selection of filter media, The Wolfson Centre has recently invested in the development of a test rig within which samples of filter media, in flat or pleated forms, can be evaluated for filtration performance and likely life cycle performance. Filtration performance is evaluated based on pressure drop over time for a conventional loading cycle, whilst service life performance is evaluated on the ability of the filter media to release particles and the subsequent pressure drop recovery towards the previous 'clean' condition. Particle 'break through' for the filter can also be evaluated during the test.

Also relevant to the use of the rig to directly help industry is its use a research tool to evaluate the effects of pleat geometry and the functional benefits of ionisation in the vicinity of the filter media for supporting the reduction of agglomerated powders impacting into the media and causing local reduction in functional filter area. The use of ionisation may also reduce pressure drop recovery time (filter relaxation) through the minimisation / weakening of dendrite formations away from the filter face.



Knowledge Transfer Partnerships (KTP)

The KTP scheme is part-funded by the government (up to 60 per cent) and part-funded by industry. It helps businesses to improve their competitiveness and productivity through the better use of knowledge, technology and skills that reside within the UK knowledge base.

The scheme enables the expertise of the Wolfson Centre to be embedded into the collaborating company, through a programme which includes the training of a new graduate to work on a project that will develop the business. This may include marketing, training, sales and other business functions, as well as technical expertise.

The Wolfson Centre is currently collaborating in a KTP project with Clyde Bergemann to create an innovative, user friendly and accurate method for the design of lean Phase Pneumatic Conveying systems. The design tool will reduce the time and cost required to produce quotations and provide a cost effective and innovative solution to improve competitiveness in key target markets

Erasmus studentships

The Wolfson Centre, as part of the University of Greenwich, participates in Study Abroad and Erasmus+ programmes enabling incoming and outgoing students and staff to benefit from experiencing new countries and cultures.

The University has been awarded an **Erasmus Charter for Higher Education** by the European Commission to take part in student exchanges and traineeships as well as staff teaching and training visits under Erasmus+ 2014-20.

International placements

The Wolfson Centre for Bulk Solids Handling Technology has an international reputation for expertise and quality of research output. This reputation results in considerable collaborative and European centric research work.

In addition to working with European Universities, the Wolfson Centre has a regular annual intake of French students from the University of Rouen, as well as welcoming international students from all over the world.

Such internships are invariably self-funded and serve as a useful vehicle by which visiting researchers can gain useful experience or insight into the fascinating topic of powder and granular science.

Technical research papers

Staff and students, past and present, have written a substantial number of technical and research papers, many of which have been presented at national and international conferences. All of these papers are available to industry.

The papers are split into technical subjects:

- 1) Pneumatic Conveying;
- 2) Hoppers and Silos/ interfacing/ flow;
- 3) Instrumentation/ flow measure;
- 4) Wear.

To obtain any of these papers listed on the website, e-mail wolfson-enquiries@gre.ac.uk.

Equipment derived from research

The following pieces of equipment were designed at the Wolfson Centre as individual Research projects. We are proud that they now form part of our wide portfolio of services that can be offered to industry.

- Brookfield Powder Flow Tester (shear tester)
- Surface Effect Segregation Tester
- Air Effect Segregation Tester
- Void Pressure Rig
- Dustiness Tester
- Attrition Tester
- Filter Media Test Rig
- Large Scale Adhesion Tester
- “K” Meter
- Fully instrumented Fluidisation Column

Best practice guide for handling biomass fuels and coal-biomass mixes

The report arose as a direct output of a PhD project, which set out to look at identifying and resolving common problems of fuel handling in co-firing of coal and biomass; however the findings are equally applicable to handling of biomass alone. The resulting document is intended as a guide for engineers, maintenance personnel, managers and procurement executives with responsibility for obtaining and operating equipment for handling of biomass either alone or mixed with coal, in solid-fuel-fired power stations.

Please contact the Wolfson Centre for your free copy



Students using the dustiness tester designed by Wolfson Centre experts

Education at the Wolfson Centre

Short courses:

Professional education for industry

The Wolfson Centre offers a series of short courses that combine technological excellence with personalised teaching. Most courses are held over two days and many now include an optional practical session in our specially built on-site pilot plant.

The dates for these courses are fixed throughout the year and are updated on a regular basis, adding and altering information as advances in technology occur. Not all courses are scheduled every year, but can be added should numbers dictate. New courses are devised and introduced to the portfolio as trends dictate.

Our courses cover a range of aspects of bulk materials handling:

Pneumatic conveying:

- Pneumatic Conveying of Bulk Materials
- Pneumatic Conveying System Design
- Rotary Valves; Design, Selection and Operational Issues
- Commissioning and Troubleshooting 'Hand's On' Pneumatic Conveying Systems

Storage of bulk materials:

- Storage and Discharge of Powders and Bulk Solids
- Design of Equipment for Storing and Handling Bulk Materials
- Biomass Handling, Feeding and Storage (can be adapted to other materials such as waste, recycled goods, pellets)

General materials handling:

- Overview of Particulate Handling Technology
- Dust Explosions – How to demonstrate DSEAR/ATEX Compliance
- Introduction to Processing Dry Solid Materials

Specialist areas:

- Caking and Lump Formation in Powders and Bulk Solids
- Undesired De-blending and Separation in Processes and Equipment
- Electrostatics in Powder Handling
- Measurement of the Properties and Bulk Behaviour of Particulate Materials
- Powder and Dust Containment
- Additive Manufacturing

Pneumatic Conveying System Design / Rotary Valves; Design, Selection and Operational Issues

“Both courses have provided good steer on present and future design work.”

Tony Robertson; Simon Carves Engineering Ltd



In company courses

Many of these courses can be delivered at your premises. These are proving to be a very popular option for companies who have a number of personnel who would benefit from education in the subject area, for three main reasons:

1. **COST:** It is more economic for us to bring the course to you, than for you to send several staff out to us;
2. **RELEVANCE:** We can tailor the course programme to suit operational requirements of your plant, hence reducing the amount of material which is not directly relevant;
3. **CONVENIENCE:** We can run the course when it suits you, even over several separate days rather than in a block if it is better for you.

ENplus accredited half day course: Quality and safety issues in pellet delivery

Half day courses approved through the UK Pellet Council are provided for drivers delivering pellets and for Quality Management staff throughout the year. Each course covers the safety and operational issues involved in the delivery of pellets to site, along with a 'Hall of Shame' to highlight real examples of bad practice. Courses for installers of domestic wood pellet boilers can also be provided upon request.

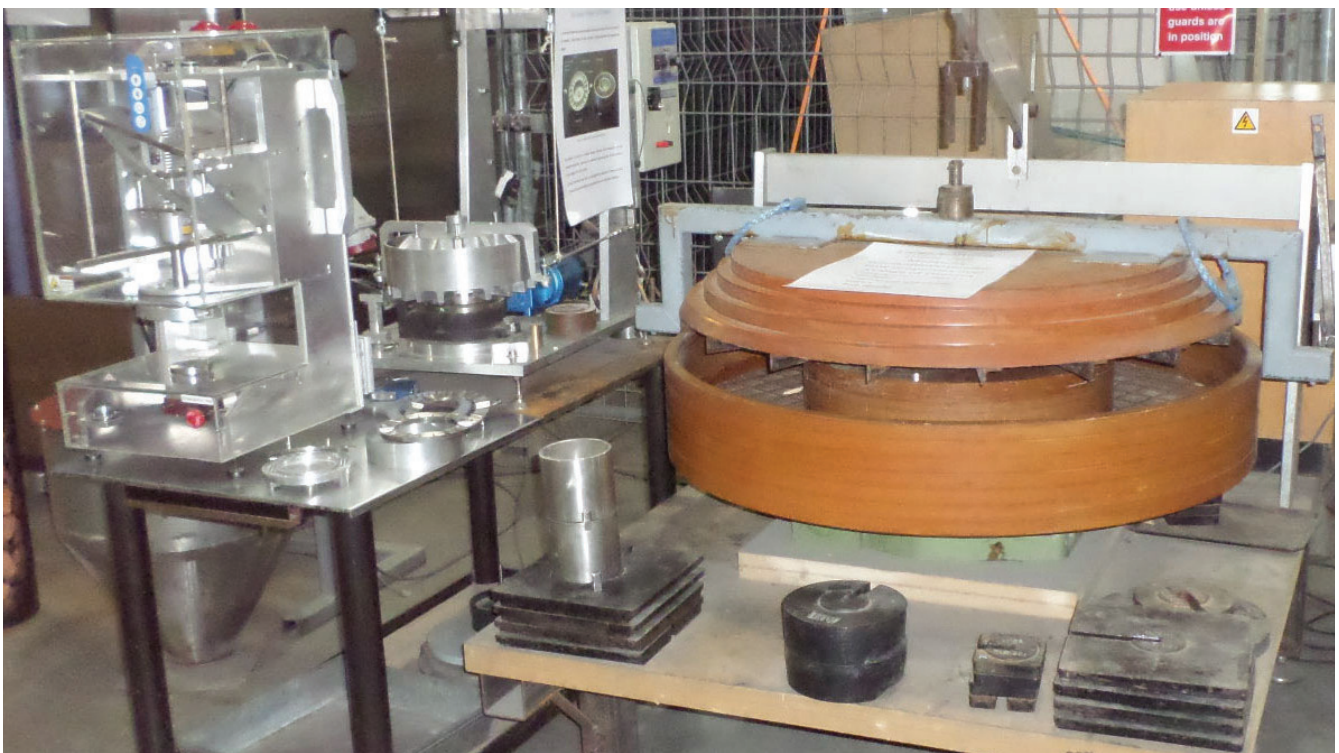
MSc Engineering (by Research)

The Wolfson Centre aims to provide high-quality postgraduate education through excellence in teaching and research.

Students who select this programme can choose to specialise in bulk solids handling. This gives them access to a field of engineering that is of great importance to a wide range of manufacturing industries, but which is only offered through formal education at a very limited number of academic institutions around the world. Our programme is designed to give students the knowledge needed to design, manage and undertake research programmes that will meet the real needs of industry. We take a caring interest in all our students and our aim is to assist them to realise their full potential.

Mechanical and chemical engineering

The science of bulk solids handling is now a recognized discipline at the University of Greenwich. Contributions are made into the under graduate mechanical and chemical engineering programmes and students are encouraged to undertake projects using the laboratory facilities.



Shear test capability has been developed to allow flow measurements to be determined for particles sized in the micron to multi-centimetre ranges

Pilot plant testing and product evaluation

Pilot plant

Using our industrial-scale facility, we can test a processing step, or mock up a whole handling process or logistics chain, at full scale or near full scale. This can be used to find and solve the problems off-line – then, when you transfer the same process or material to your own or your customers' plant, you can be confident it will work.

Our plant extends over 450m² and includes:

- Pneumatic conveyors
- Belt and mechanical conveyors
- Screening machinery
- Blenders
- Feeders (vibratory, screw, belt and others)
- Presses
- Transport simulators
- Granulation and pelleting facilities
- Size-reduction facilities
- Environmental test facilities
- Control systems rigs.
- Air Filtration Rig

We also have the flexibility to obtain and install most items of equipment not currently in our plant.

Frequent pilot plant test project objectives include:

- Assessing a new or reformulated material to determine if it will go through the existing systems or if changes are needed to accommodate it
- Setting up a short production run on a proposed new powder-route product to test formulation and manufacturing proposals
- Testing a proposed new handling system or item of equipment.

Equipment development

You may have plans or ideas for a novel or innovative solids processing method or equipment item. We have the facilities and expertise to develop and test it, and bring our expertise into the development to help it come to market quickly. These projects are confidential, the work does not need to be published and we have a sensible approach to intellectual property ownership. We also

have many contacts with manufacturers and sellers of equipment, which may be useful.

On the other hand, you may simply have a unique solids processing requirement which is not covered by equipment in the market. We have the ability to identify, test and measure critical process parameters and come up with the best solution, whether it be a totally innovative idea or a modification to existing equipment.

Development of novel bulk particulate materials

If you are developing a new or modified powder, granule or particulate material, we have the skills and expertise to help you optimize or verify its performance, quality, profitability and customer appeal. Again, such work is completely confidential

Characterisation equipment

- Powder Flow Tester
- Dynamic Vapour Sorption
- Atomic Force Microscope
- Size Analysis sieves
- Picnometer
- Laser Diffraction (wet and dry)
- SEM imaging
- XRD/XRF



The evaluation of bulk behaviour at close to industrial scale can be undertaken using our extensive pilot

Meet the Staff

Prof Mike Bradley Director	m.s.a.bradley@gre.ac.uk	Pneumatic conveying systems and biomass handling issues
Richard Farnish Consultant Engineer	r.j.farnish@gre.ac.uk	Optimising packaging and tanker filling systems
Dr Robert Berry Consultant Engineer	r.j.berry@gre.ac.uk	Powder flowability
Dr Tong Deng Research Fellow	t.deng@gre.ac.uk	Wear and electrostatics
Dr Hamid Salehi Kahrizsangi Post Doctoral Researcher	H.SalehiKahrizsangi@gre.ac.uk	Virtual Formulation Laboratory project
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Parking is available on site, though a pre-booked permit system.

For details on directions and public transport links, please visit <http://www2.gre.ac.uk/about/travel/medway>





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