Inside Manufacturing Enterprise (IME)

Case Study

- The aim of this case study is to give teachers a resource to use when preparing for or following up a visit to **Ideal Standard International-** a host company involved in the IME regional company visit programme which is designed to give schools access to some of the best manufacturing and engineering companies in the West Midlands.
- It can also be used as a stand-alone teaching aid.
- The case study supports the teaching of **Manufacturing, Engineering, Systems and Control and Product design.**

Case study prepared January 2009 by Staffordshire STEM Centre with the help and support of Ideal Standard International, Armitage, Staffordshire

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Section 1. Production and Assembly- A general overview

Construction and assembly of parts has become increasingly automated since the introduction of computers to production lines. The punched paper tape used in numerical control has been replaced by computer programs controlling the work of machine tools (CNC). This gives a greater accuracy and consistency of production of parts. Skilled human machinists are often being replaced by CNC controlled machines and their unskilled operators.

In addition to the machine tools, other areas of the production line are becoming automated. Robots often take the place of humans who previously assembled the parts and constructed the finished product. Flexible manufacturing systems (FMS) have been introduced where a computer has control of the entire production line. Machine tools, robots and conveyor belts are linked to a main computer. This not only controls the processes but can report the progress of each work piece as it goes through the system.

These systems are also very adaptable and allow new products and specifications to be introduced by inputting data to the FMS program software. This automatically updates the system and so retraining of staff or manual resetting of machinery is not required.

Production-a comparison of Traditional Manufacturing and Computerised Manufacturing:

Traditional Manufacturing	Computerised Manufacturing
Skilled manual workers operate lathes and cutting tools by hand. This requires experience and training. Workers must have the ability and skill to adapt to changes in task specifications.	Semi-skilled/ skilled operatives oversee machine tools which are already programmed to automatically cut patterns and shapes. The job remains the same for the worker regardless of changing tasks carried out by the machine tools.
Unskilled and semi-skilled manual workers sort	Sorting and assembly is often carried out by computer

and assemble parts manually. Products are lifted manually.	controlled robots. Heavy products can be lifted easily by robots, removing the need for operators to do very heavy lifting.
Most parts and assembled goods are inspected as a part of the quality control process.	Programmed machine tools and robots produce work of a standard quality and therefore only random quality testing is carried out. Some FMS systems incorporate their own quality control.

'The Impact of of Computers in Manufacturing: A Gibson'

Design and Testing

The introduction of computers has also greatly changed the way design and testing of products is carried out. The conventional methods of drawing designs by hand and building prototypes for testing have been replaced by Computer-assisted Design Technologies (CAD).

Computer-assisted Manufacturing technologies (CAM) is an extension of CAD design which determine the quantities of materials needed and instructions required to produce an item. These have further changed the engineer's role.

The combination of CAD/CAM technology relies on the capability of computers to process, store, display and transmit large amounts of data, quickly and without degradation of quality or content. The combined technologies are often referred to as Computer-assisted/aided Engineering (CAE). These are able to give instructions directly to the FMS systems controlling the productions line, through Local Area Networks (LANs), without the need for human intervention or communication.

Design and Testing- a comparison of Traditional Manufacturing and Computerised Manufacturing:

Traditional Manufacturing	Computerised Manufacturing
Engineering designers work with paper and drawing equipment. They produce one or two dimensional diagrams and plans.	Engineering designers work at computers, using CAD software to produce two and three dimensional diagrams and plans.
Plans often have to be completely re-drawn if testing fails.	Using CAD the designs can be quickly and easily amended.
Engineering designers working in teams have to work on one paper drawing at the same time or make amendments to photocopies.	Engineering designers can work at the same time on the same design used shared resources and linked computers.
Testing of new products is carried out by building scale models or prototypes.	Testing is carried out using computer simulation offered by CAD technology.
Engineers are required to breakdown designs into parts, estimate raw materials required and write the working instructions for production line workers.	CAM technology calculates the raw materials required and transmits data containing instructions directly to the automated production line.

'The Impact of of Computers in Manufacturing: A Gibson'

Section 2. Overview of Ideal Standard International

a) History

From this   to this

The company started in 1817 in the village of Armitage. The canal was used for transporting clay from the Stoke area. The company changed hands many times but by 1851 was making only bathroom products. Armitage Shanks was formed following a merger with a Scottish sanitary engineering company in 1969. The company opened factories in Africa, Australia and Asia in the 1970's. In 1999 it became part of the American Standard group of companies. It is now one of the largest manufacturers of sanitary ware in the U.K.

b) Site details and developments

In 2000 the site changed from a multi level to a single level 'Dft' Layout (Design Flow Technology). Since 2001 £9,000,000 has been invested into the site. There are 421 employees on the site (plant/warehouse) of which approximately 303 are operational. Due to the new technology there are fewer staff required on site but a third of the staff are engineering based. This site is described as 'cutting edge' with high technology. This is common in European companies but not in the rest of the UK.

Although this is a highly automated factory with robots throughout, skilled engineers are vital to the company. It is the engineers who make the difference, create the design and set up the robots and processes. They adapt designs and processes to suit the changing markets and customer needs which allows the company to move forward. The Team Leaders are managing smaller teams of people now that the processes are so automated. They still need to have 'man management' skills but must have the engineering skills to manage the high-tech plant. This is common across all high volume manufacturing organisations. There are specialist technicians within each area of the plant- not just manual workers and whilst not many people are seen on the factory floor there is a considerable amount of technical work going on behind the scenes.

The total area of land occupied is 169,000 m2 but the size of the plant working area is only 22,000 m2. Although a smaller working surface area there is higher production than before. The low variety, low complexity of products produced here allows for high volume production at an economic cost.

There is capacity on site to produce 2,000,000 pieces of ware a year through a 24hr/7day operation. In 2008, over 1,600,000 pieces were produced but volumes may be reduced for 2009. Shutting kilns down is not economic as it is far better to keep them running for 24 hours a day.

In 2004 the company changed to pressure casting using resin moulds. This means the casting process is far more productive and of a higher quality. Traditional slip casting moulds made out from plaster can only be used a small number of times before they have to be allowed to dry out. Water from the clay slip passes into the plaster allowing the clay to become more solid so that the mould can be taken apart after a short time. Resin moulds dry out more quickly.

A stand alone highly automated ‘tank cell’ is also used which does all of the casting, spraying and firing. The robots have taken away the heavy lifting from operators now, reducing the sprains and repetitive stress injuries traditional processes caused to Operators. At the wet clay stage one piece of ware can weigh 18 kilos with a set reaching a maximum of 25 kilos.

Although automated the aim is to keep it simple and as efficient as possible- production can become over technical otherwise for no reason, simple is efficient.

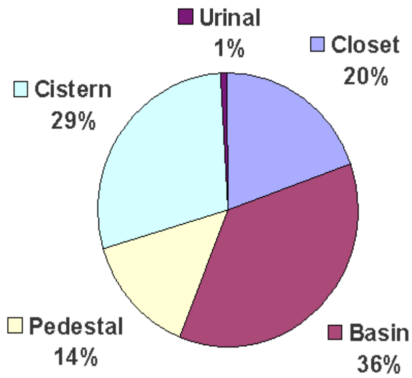
Designing

There is some piece-meal planning but new developments are mainly worked on by the teams of production managers and engineers who work on the new designs with the marketing team. The Hull site of Industrial Standard International employs many of the Design engineers and Ceramic engineers. The design brief is prepared depending on whether it is for the commercial, domestic or luxury end of the market place. Once it has been decided what is needed, an initial 3D sketch/design is made using Computer Aided Design (CAD). Computer Aided Manufacturing machines (CAM) then uses this data to machine the new moulds the sanitary ware is produced from. A trial mould is then used to carry out low-production volume trials. This is checked by the designer and if satisfactory goes down to the manufacturing plant level industrialisation engineers. These engineers will see how the low volume prototype can move to high volume production. All stages of production are considered including the logo, type of glaze, drying period and required position in the kiln for correct firing. The whole team is involved in this. The moulds/cases are then produced- some at the Armitage factory, some at their other factories in the UK.

c) Product and Markets served

The Armitage site produces sanitary ware mainly for the non-residential market, including hospitals, stadiums and large plumbing wholesalers and DIY stores. 90% of their market is UK sales (Figure 2). They produce a range of sizes and functions of basins and closets. Most pieces produced here are white. Figure 1 shows the percentage of each piece of the overall number produced. The pieces are sold separately. This is easier to package and distribute. Further down the production chain pieces may then be put together.

Figure 1



When designing and manufacturing the pieces, health and safety plus legal requirements must be taken into account. The design must ensure the connections to sewers have effective seals to avoid gases and foul smells. Their customers may have different health and safety requirements to address, hospitals and care homes particularly so. To avoid bacterial growth in hospitals, clinical hand washbasins are provided- called ‘sink to drain’ by the Company. A clinical hand washbasin consists of lever-operated mixer taps mounted on the wall above the basin, with no plug and no overflow. The technical side and customer requirements are critical to the development of the Company’s production processes.

The product specification (‘Spec’)has details that are relevant to the customer and includes such details as the dimensions, weight, and colour required. The manufacturing specification contains details that are relevant to the making of the product and includes details about which tools to use, how long it will take to cast, dry and fire the ware.

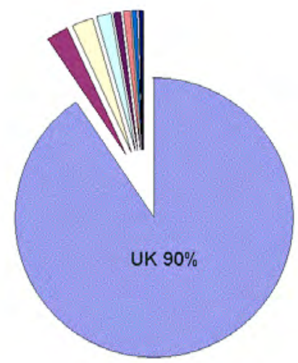
d) The Processes

As the clay has come from the ground (a natural material) it will vary and have different moisture contents. This is not acceptable for manufacturing so the clay has to be mixes and processed to make it more uniform. A recipe is used for the mix to make sure the products produced will be of a consistent high quality. The mix even includes adding anti-bacterial agents.

The liquid based clay called slip is produced on site. As far as possible everything throughout the process is recycled if not used, whether the clay- water- glaze or energy by products of the kiln.

Mostly the fired waste goes elsewhere for reprocessing and it is then sold back to industry, for example converted into gravel for pathways.

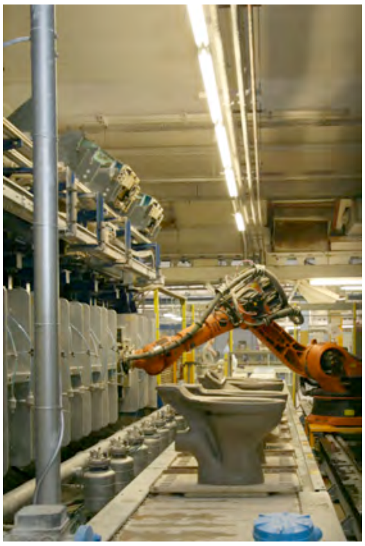
Figure 2



Traditionally the slip was poured into plaster moulds. Resin moulds are now used in the casting process which achieves a higher quality than with plaster ones. The only plaster moulds still used produce the small buttons that go inside the closets (Traditional toilet bowls, water closet or WC). The closets are ‘over designed’ in order to allow an extra margin of strength for safety to cope with a 160 Kg person. The casting time is important in order to get the thickness, strength and geometry of the product right.

Casting

After the clay has been mixed the slip is poured into the casting machines. (The closet casting machine has 8 moulds on it). The mould is filled with the slip and is then drained away leaving only the residue clay closet behind. It is only in the casting machine for 30 minutes. The resin moulds dry much quicker than the plaster moulds. The casting machine is flushed through every three weeks to maintain it.



Cistern lid after casting

Robots in action- taking closets off casting machine

Robot

Sponged by hand

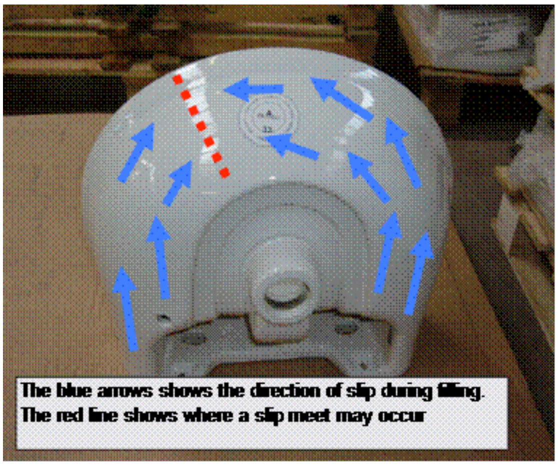
Cisterns

The cisterns have holes for the connective pipe work punched into all sides to allow for flexibility in final fitting. The unused holes are fitted with blanking caps by the plumber that finally fits the cistern into a building. Each product has a unique bar code applied at this stage which is placed at the rear or inside if necessary and remains after firing. This allows the robot computer control system to know what they are dealing with. The data capture system allows the system to identify who did what at which stage of the process and which mould the product came from. This provides in depth knowledge and traceability of the process that can be analysed later if for any reason the product fails or is returned by the customer. This allows for continuous improvement.

Basin Mould

Basin after casting and sponging

One problem that can happen is 'distortion-turbulence'. This is caused by the platelets in the clay and is called 'slip meet'. A pot suffering from 'slip meet' will have a ridge where the 'meet' occurs. This would result in the pot being rejected during inspection. Slip meets can be hard to cure. The design must compensate for this retraction. The usual solution would be to model the pot with a distortion already built in. This would then counteract the ridge caused by the slip meet.



'Slip meet' is a term used to describe a fault in the pot and happens as the mould is filled with the slip. Imagine the inside of a basin mould filling with clay from the bottom upwards, the slip will firstly fill the base of the mould and then travel upwards. The 'slip meet' will be located at the point where the last bit of air leaves the mould and the slip meets together.

The arrows in the diagram show the direction of the slip during filling. The red line shows where the 'slip meet' may occur.

The moulds for some of the products have 'male' and 'female' parts and must match to make the complete product. These moulds need to compensate for the moisture and changes throughout the process and kiln changes. This is highly technical but does rely on some trial and error as well as experience. After the moulds process there is less than 1% waste at this point. The technical teams in the laboratories work continuously to improve the processes following the Six Sigma quality approach (see Production Control Process).

Initial Sponging

The robot picks up the product and takes it to the Sponger who sponges off residue clay by hand. The products are then put onto the conveyor belts. The conveyors go from around the plant into the kiln tunnel area.

Sponging closets and basins

Drying

As the products travel round there is a subtle change in colour as moisture is gradually released into the air.

The moisture level is critical as too much moisture will turn to steam in the kiln and the product would explode. The speed of drying is only important if different parts of the product dry at different rates as stress and cracks will occur. The dimensions and accuracy of the products are very precise and are accurate to 1/10 of a millimetre of the specification sizes. As a three dimensional object the product will change in size in all three dimensions with a 12% reduction in size as it dries and is fired. There will also be permanent changes chemically and physically to the clay because of the heat in the kiln.

Closets and cisterns must fit together with tap holes made in the correct places appropriate to the model being made. Different models and sizes will go along the conveyors at the same time.

Conveyors taking the products around the factory

Dimensions change as products go through the different production processes

Sponging

The products are sponged before the glaze is applied to ensure the glaze goes on smoothly. As there is a high level of sand in the clay there is considerable dust at this stage. To avoid risk to the health of operators and to protect them from the dust products are sponged inside booths which have extraction and air filters.

Sponging

Robot spraying glaze

Glaze Spraying

This is carried out by a robotised spraying line. The robots have protective covers. Products are sprayed four times. The first robot sprays the inside. They have unique programs with system recognition to allow for auto selection. The robots know exactly what type of product they are picking up because of the bar code and will spray to match information in the bar code. The robots only spray the white products. The programmed machine tools and robots produce work of a standard quality and therefore only random quality testing needs to be carried out for high volume low variety production. The products dry very quickly as the moisture goes back into the clay and not the atmosphere. All sides of a cistern are evenly glazed. A few pieces for special orders only have one side glazed. This is harder for production and also increases process costs. Hand spraying is carried out by human operators for different shaped products and colours.

Hand spraying

Closets after spraying

Location of bar code inside closet

Completed product after glazing and kiln firing

Kiln

The products are placed on the kiln cars by the robots. The kiln cars move the full length into the kiln which is a heat resistant long brick tunnel with gas burners which heat the kiln to 1200°C. The flame goes underneath the products not onto it. The kiln is a continuous pull through kiln that has a moving track the cars fit onto. The glaze melts and fuses to the clay surface which produces a high gloss finish. Glaze is made up of the chemicals silica, alumina and a flux. Silica is the glass forming part. Alumina stabilises the silica so that it does not run easily when heated to form a liquid. It takes 17 hours to heat up and for the products to go through. The firing and cooling process is very important. When heated up the products are like glass, if heated up or cooled too quickly they will shatter.

Kiln and trucks

Glost inspection

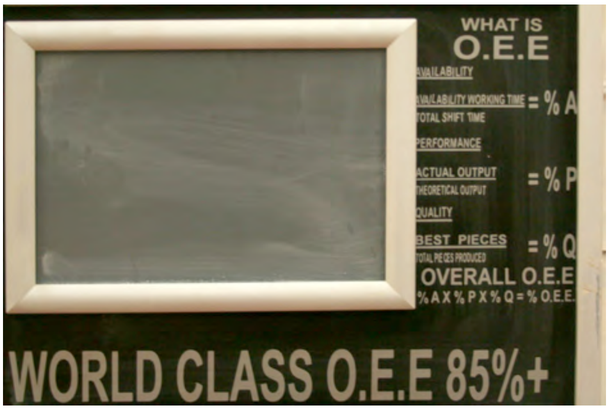
After firing of this 'glossed or glazed' ware and it is cool enough to handle there is 100% inspection of the products whilst on the kiln cars. This is known as glost inspection. If not satisfied with the quality some may be re-fired, thrown away or recycled.

The Automated Tank cell

This is a series of robots that stand alone and carry out all the casting, punching and spraying processes of the cisterns right through to firing. The robots are programmed to know the sequence of work, the style and which piece of ware to match with another.

The moulding tools on the robots are all changed manually. Robots can do this but they take longer than an Operator. This must be taken into account when looking at production costs.

Production Control Process



Targets on display boards around the factory

The production process uses aspects of several different manufacturing philosophies, including Lean, Six Sigma and the 5S Quality Improvement Process. They do not operate a ‘no fault forward ‘ system as it can be sensible to rectify some faults downstream in the production process.

Six Sigma is a process used to identify and remove the causes of defects and errors in manufacturing and business processes. It uses a set of quality management methods, including statistical analysis. A number of people within an organisation are trained up as ‘black belts’ and have the expertise to review and improve business processes and solve problems that result in errors or poor production. Each Six Sigma project carried out within an organisation follows a defined sequence of steps and has quantified financial targets (cost reduction or profit increase).

As the company invests a lot of time in training and its technical developments, parts of the plant have areas where the teams meet to review their Quality Action Plans, audits and targets. These are posted on display boards. The 5S Quality Improvement process is followed to assess the organisation, health and safety and housekeeping within the area and whether or not the machines are working effectively or not.

This is a visible management indicator and a spider diagram is used for all teams to see improvements. Red tags are placed on machines if a member of the team is not happy with the performance after carrying out a series of audits. The training and performance audits are most important to a company when the economy is in a difficult situation. 5S Quality Improvement is a set of business techniques providing a standard approach to housekeeping within ‘Lean Manufacturing’ to ensure that the company can compete with rivals. 5S stands for Sort, Set in Order, Shine, Standardise, Sustain.

5S originated, as did most of the elements of JIT (Just in Time) within Toyota. The aim for JIT is to have each individual component to arrive exactly when required - in other words, ‘just in time’- JIT. Lean Manufacturing means the elimination of waste in production which includes -Defects, Overproduction, Waiting, Transporting, Movement, Inappropriate Processing and Inventory.

Having a manufacturing system that is well organised will help the company to launch new products quickly once a poor economic situation improves and before its competitors.

e) Summary of the Process Technology at the Armitage site

1. **Automated Cistern Casting, Punching & Placing**:
    - Improved Quality & Yields
    - Reduction of Manual Handling (Repetitive Strain Injury)
    - Improved Productivity
    - Increased Flexibility
2. **Automated Five Part Closet Casting & Demoulding**:
    - Improved Quality & Yields
    - Reduction of Manual Handling (RSI)
    - Improved Productivity
    - Increased Flexibility
3. **Automated Spraying with Xtract Glaze Recycling System**:
    - Minimal Glaze Wastage
    - Consistent Application
    - Improved Quality

Section 3. Useful website links

http://www.technologystudent.com/ - A design and technology site which contains numerous information sheets and exercises to enhance study, the understanding and teaching of Design and Technology
http://www.robot.org.uk/ - This site is a guide for robot builders
http://www.bbc.co.uk/schools/gcsebitesize/design/ -revision notes for design and technology, including systems and control
http://www.armitage-shanks.co.uk/about.html - Ideal Standard Armitage website
http://www.ideal-standard.co.uk/aboutus.aspx - Ideal Standard International website
http://www.geocities.com/angiemgibson/essay.htm -Computers in Manufacturing- Angie Gibson
http://www.proskills.co.uk/download/Ceramics%20Final%20Draft%20QS.pdf Qualifications Strategy for the Ceramics Industry- Association for Ceramic Training & Development (ACTD)
http://www.actd.co.uk/ -Association for Ceramic Training & Development (ACTD) is the National Training Organisation for the ceramic industry

Teachers Notes

Section 4. How to use this case study

This case study is intended to support teachers and students, particularly Years 10, 11 and 12 when studying **manufacturing, engineering, systems and control and product design**.

Ofsted fully recognises the value of learning outside the classroom as being most successful when it is an integral element of long-term curriculum planning and closely linked to classroom activities. This case study if used with students to prepare them for and then follow up from a visit to Ideal Standard International will support you in achieving this as well as the goals within the '*Learning outside the classroom'* manifesto.

As a standalone resource it will give a valuable insight for students into the **high tech automation** and production processes used to produce what appears to be a low tech product. It also provides an indication of which of the relevant student learning outcomes and projects intended within the **manufacturing, engineering, systems and control and product design GCSE's** it can help students achieve.

From 2009 students will be embarking on the **Manufacturing and Product Design Diploma.** This case study along with the company visit will help to reinforce their skills, knowledge and understanding of Manufacturing and Product Design and offer an insight into the specialist learning of robot technology.

Section 5. How to arrange a visit to the company

A typical visit to Industrial Standard International lasts approximately 1 hr 30 minutes and includes:

- Introduction and Health & Safety talk
- Viewing of Manufacturing Facility
- Summary and Q&A session

The maximum group size is 15. The main safety issues to be aware of whether working or visiting such a manufacturing site include slips and trips so stout shoes are required. Safety overshoes and Protective Eye glasses will be provided.

To arrange a visit contact **Staffordshire STEM Centre**;
Room C146, Faculty of Computing, Engineering & Technology
Staffordshire University
Beaconside
Stafford
ST18 0AD Tel: 01785 353348 Fax: 01785 353363
Email: stempoint@staffs.ac.uk
Website: www.staffsstem.co.uk

Photographs: If you would like copies of any of the original photographs which were taken during a school visit to Ideal Standard International in January 2009 as a classroom resource please contact the STEM Centre.

Section 6. Learning Outcomes

This case study can support the following subject criteria:

Subject	Learning Outcomes	Knowledge & Understanding of
GCSE Manufacturing	Gain an understanding of the contribution that manufacturing makes to society and the economy Develop an awareness and appreciation of commercial and industry issues, and of emerging technologies, in the context of manufacturing	**Production details and constraints:** Materials and components Available technology Health, safety and hygiene Quality standards. **Materials, components and/or ingredients and their constraints:** Their properties, characteristics and performance **New technology used in and by the manufacturing industries:** Systems and control technology, to organise, monitor and control production. **Impact of modern technologies:** When manufacturing a product On manufactured products On manufacturing industries Stages in manufacturing a product Advantages and disadvantages that the use of modern technology has brought to society. **Manufactured products:** Investigate a variety of manufactured products that use modern technology. Investigate the impact of modern technology on the design and production of a range of manufactured products. **A range of manufacturing industries:** Research and analyse existing products, materials and manufacturing processes and market needs
GCSE Engineering	Understand the contribution that engineering makes to society and the economy Develop an awareness and appreciation of commercial and industry issues and emerging technologies in the context of engineering	**Engineering materials and their properties in the following groups:** Ceramics **The functions of:** Mechanical components Electrical/electronic components Pneumatic/hydraulic components **The properties, characteristics and features of materials that affect:** Ability to be shaped and formed Ability to be treated Ability to be given a surface finish Ease of handling Cost implications **Engineering processes:** Material removal Shaping and manipulation Joining and assembly Heat and chemical treatment Surface finishing **Quality control techniques** **new technology used in and by the engineering industries:** Systems and control technology to organise, monitor and control production **The impact of modern technologies:** When engineering a product On engineered products

		On engineering industries On stages in engineering a product Advantages and disadvantages that the use of modern technology has brought to society **Engineered products:** Investigate a variety of engineered products that use modern technology Investigate the impact of modern technology on the design and production of a range of engineered products
AS/A Level Design & Technology Product Design	The use of digital technology in designing and manufacturing processes Health & safety issues Quality Assurance Engineering materials Manufacturing Processes Manufacturing, Production & Planning Manufacturing Systems & Controls Manufacturing Methods	High volume production and automation The protection of the worker/operator The protection of the user/customer Quality control Quality assurance ceramics and ceramic composites High volume production systems continual flow in-line assembly automated production robotics The implications of these industrial production processes/ procedures Appropriate manufacturing methods that take into account the properties of different materials The effects of the manufacturing process on the properties and structure of materials preparation of materials Processing of materials Assembly stages during production Sequencing and timings of manufacturing stages Production planning Monitoring, testing and tracking during production Robotics, automation Processes, materials and components used to manufacture products from differing materials
Manufacturing and product Design-High Level Diploma	Science and Design 2.4A	Good manufacturing design and development The importance of research, design and development Factors affecting the design and manufacture of a product (for example cost)
Manufacturing and product Design-High Level Diploma	Business and Enterprise 2.4B	Develop design ideas for a prototype, using CAD where appropriate Product design specification to meet a client brief or product research Analyse whether the features and benefits of a designed product meet the clients' needs
Manufacturing and product Design-High Level Diploma	Business and Enterprise 2.5A	Materials, scientific processes and principles used to increase productivity and sustainability Testing analysis and measurement methods Chemical, biological and physical properties
Manufacturing and product Design-High Level Diploma	Business and Enterprise 2.5B	Scientific terminology, symbols and units Material preparation in line with health and safety and organisational guidelines
Manufacturing and product Design-High Level Diploma	Production systems 2.6A	Different processes and systems used Maximising efficiency and effectiveness through use of technology How the processes and systems would differ if a product was manufactured in different quantities What might happen if health and safety legislation and guidelines are not followed Control procedures used for the safe use of tools, equipment

		and plant
Manufacturing and product Design-High Level Diploma	Production systems 2.6B	Critical control points needed to maintain product quality Measuring equipment used to monitor quality of a product Calibrate equipment regularly and accurately Apply control techniques safely in line with relevant legislation and guidelines Use measuring equipment safely to check quality to a given tolerance
Manufacturing and product Design-High Level Diploma	Production systems 2.7A	Product design specifications, standard operating procedures and integrate operations Health and safety and environmental guidelines Maximising efficiency (for example, lean manufacture and maintenance systems) Environmental impact and cost of remanufacture, recycling materials and safe disposal of waste materials
Manufacturing and product Design-High Level Diploma	Production systems 2.7B	How products and materials are packaged, transported and stored Standard operating procedure in line with specification and agreed tolerances (for example, setting up or calibrating equipment)

We are extremely grateful to Ideal Standard International, Armitage for their help and support in the preparation of this case study

Armitage site