



Imperial College carbon capture pilot plant

Preparing today's students for tomorrow's world

Planting the seeds of change today

Shaping tomorrow's engineers

By supplying equipment for Imperial College's carbon capture pilot plant, ABB aims to equip today's students with the skills needed to run tomorrow's industrial processes. The only facility of its kind in an academic institution in the world, the pilot plant shows students how the latest technologies can help to optimise plant performance and safely manage emergency situations in real-life applications.

The opportunities for ABB and Imperial are immense. The facility provides a once in a lifetime opportunity to influence the training and education of thousands of young chemical engineers over the next 20 years at one of the world's premier chemical engineering departments.

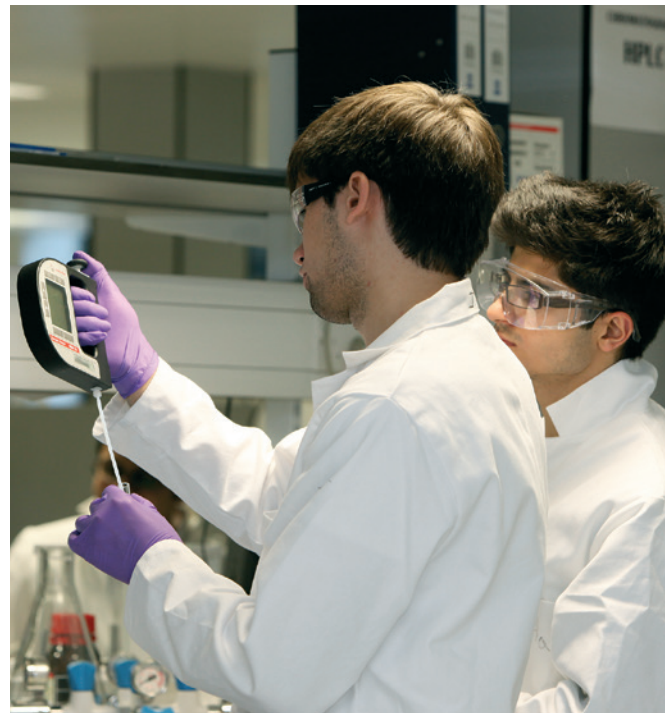
The agreement between ABB and Imperial College gives the university access to the most advanced control and instrumentation technology available from any manufacturer, as well as life cycle services and support for the installation.

In return, ABB has access to the carbon capture pilot plant for its own use and will use the facility for customer demonstrations and training, staff learning such as inter-divisional training and hands on experience for its apprentices and graduate engineers.

ABB will be able to trial new technology in a low risk, well-managed environment to gather Beta site test data. Quite simply, there are very few industrial companies that have utilised all the leading-edge technology that Imperial is featuring within this pilot plant.

With many international students also studying at Imperial, the facility will help to position the UK as one of the global centres of excellence and expertise for engineering education. For ABB, there is the added attraction of building awareness of its technologies and capabilities across a global audience.

The increasingly global nature of the projects that ABB are involved with, particularly in the oil, gas and petrochemical sectors, means that engineers from the UK and elsewhere are being called on to work in many different regions worldwide. The aim is to use the plant to create a lasting association between the real-life problems that students will encounter once they qualify and the technology and capabilities available from ABB that can help solve them.



Lessons in the power of integration

A joined-up approach to teaching

Bringing industry into the classroom

The carbon capture pilot plant is part of Imperial College's £8.9 million ChemEngSpace project and will be used for undergraduate teaching, with over 300 chemical engineering students having access each year.

The CO₂ pilot-scale absorption plant uses an extensive selection of the same ABB proven products and systems that are used in a broad range of industrial applications worldwide.

The plant is designed so that students get hands-on experience of ABB's product and system integration by showing them in action in a cutting-edge industrial application. By using this equipment, students can gain valuable practical experience of plant operation that will help prepare them for the industrial challenges of tomorrow.

Together, ABB's control systems, process instrumentation, variable-speed drives, motors and electrical controls, give operators everything they need to run their plant efficiently, safely and with minimum environmental impact.

ABB has provided a wide variety of products for use in the plant, including:

- System 800xA distributed control system
- 800HI SIL3 integrated safety control system
- Extended Operator Workplace (EOW)
- Pressure and differential pressure transmitters
- Temperature sensors and transmitters
- Electromagnetic flowmeters
- Swirl and vortex flowmeters
- Variable area flowmeters
- Coriolis mass flowmeters
- Differential Pressure (DP) flowmeters
- Level measurement
- pH analysers
- CO₂ gas analyser
- Smart valve positioners
- Paperless data recorders
- Low voltage AC drives and motors
- Low voltage electrical products

Imperial College carbon capture pilot plant

How the process works

— 01 The plant uses over 250 instruments, measuring parameters including temperature, pressure, pH, level, carbon dioxide and flow

— 02 The plant has a capacity for 50 kg per hour capture of carbon dioxide

— 03 The construction of the plant is part of Imperial College's £8.9 million ChemEngSpace project

Finding ways to mitigate the effects of industrial activity on the environment is assuming ever greater importance in the fight against climate change. With CO₂ from industry and power generation contributing to rising global temperatures, new ways need to be found to help reduce the quantities of CO₂ being emitted to atmosphere.

As a means of capturing and locking away CO₂, carbon capture and storage is increasingly being seen as a viable way of tackling the problem.

Step 1

Carbon dioxide (CO₂) and nitrogen enter the system (1). The gas mixture is passed into a saturation vessel (2), so that the CO₂ becomes saturated with water before passing into the absorber tower. This helps with the subsequent CO₂ absorption process.

Step 2

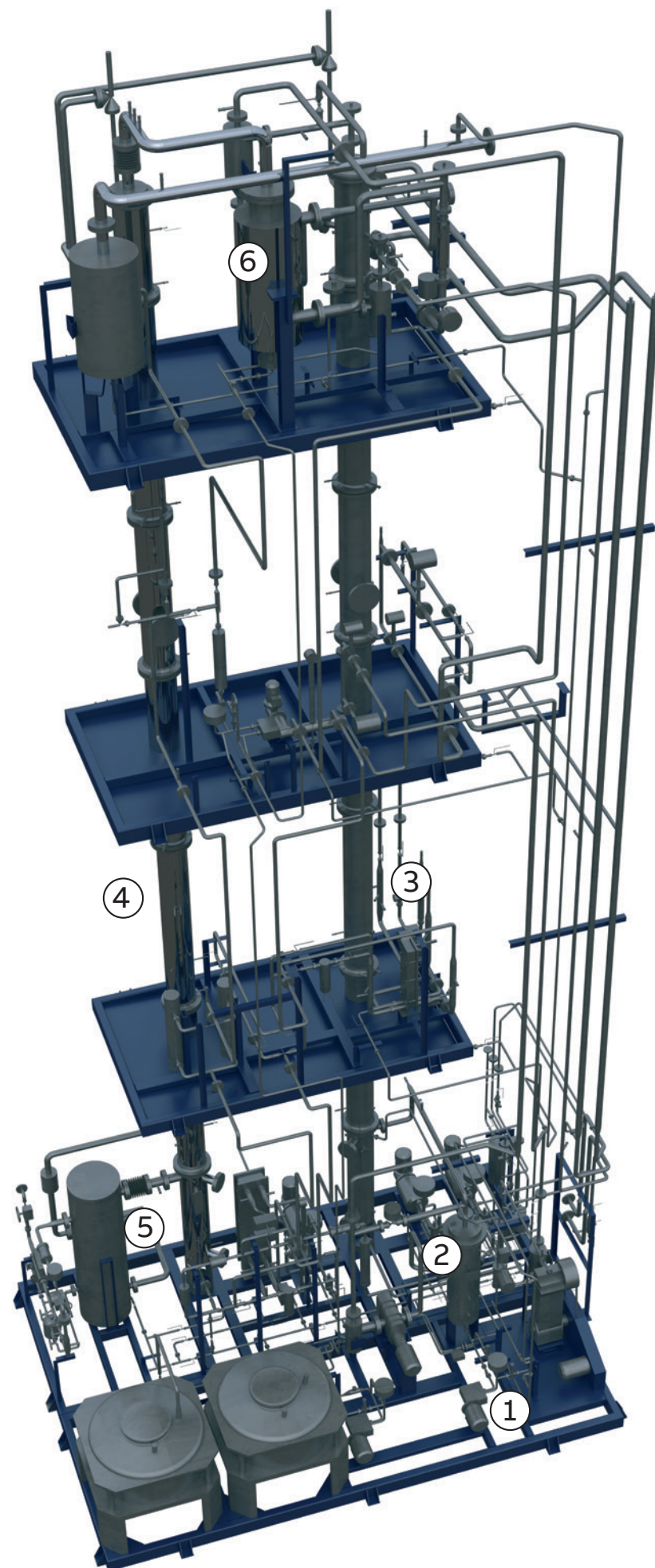
The gas rises up the absorber tower (3) as the Mono-Ethanol Amine (MEA) solution flows down from the top. The CO₂ absorption process requires specific pressure, temperature and pH conditions.

Step 3

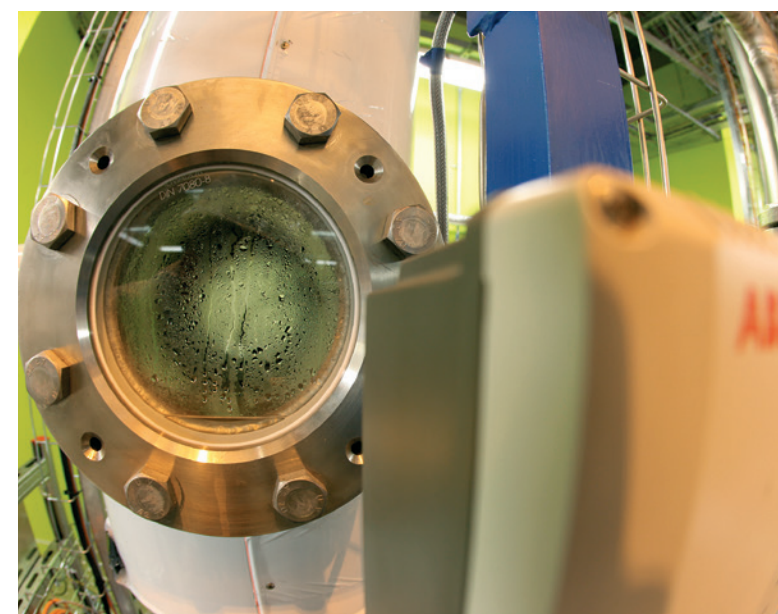
The CO₂-rich amine solution is pumped to the top of the regenerator tower (4). It then flows into the re-boiler (5) by natural convection processes, where the liquid is heated and a fraction turns into vapour.

Step 4

The vapour passes up the regenerator tower into the condenser (6) where the amine solution condenses, leaving the CO₂ as a gas to be collected. The CO₂-free liquid MEA returns to the regenerator and is then pumped back to the top of the absorber tower (3).



01



02



03

The ABB control room

Main features

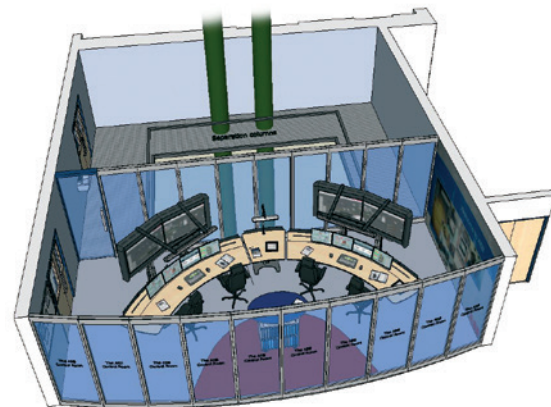
All information from the process is relayed to the ABB control room, from where students can monitor and control every aspect of the plant.

Over 250 separate process instruments provide real-time feedback on flow, temperature, pressure, level, pH and CO₂ levels. This data is fed to the control system via several different communication protocols, including Foundation Fieldbus, Profibus DP, Profibus PA and Wireless HART, where it is then shown as part of the real-time process display on dual extended operator workplaces.

Using the latest iPad technology, the plant operators can also remotely monitor the process whilst working outside of the ABB control room.

Ergonomically designed operator interface

Information from the plant is relayed to the operators via the various display screens. Updated with real-time data, these screens provide a comprehensive picture of all aspects of the plant's operation.



Getting the data to the control room

The real-time data from the plant room is relayed to the control room via ABB's AC800M control technology. The AC800M integrates various networks, fieldbuses, serial protocols and I/O ready for presentation to the System 800xA as well as handle the real-time control of the plant.



Advanced control and instrumentation technologies

Harnessing the world's most advanced designs

Powering instruments using energy harvesting

Energy harvesting provides new and cost effective options for powering wireless instruments.

The cost and power challenges of networking instruments

Wireless instruments offer the ideal solution wherever it may be costly or impractical to run cabling. Battery-powered WirelessHART technology allows for quick and simple instrument installation to allow operators to monitor new process information to improve plant visibility.

However, the battery will eventually need replacing, incurring time and cost. Battery life can be prolonged but only by slowing down the data transfer rate, affecting the instrument's response time.

The solution is to use remote instruments powered by energy harvesting technology

The Imperial College pilot plant features ABB temperature transmitters fitted with ABB's FieldKey WirelessHART adapters and another transmitter using an integral thermal gradient energy harvester.

The FieldKey adapter is for applications where there is local power available but no signal cable back to the control room. It harvests energy from the 4-20mA loop and adds WirelessHART connectivity to any HART instrument. At Imperial College, temperature instruments with FieldKey adapters are installed on a column, relaying process data back to the control room via WirelessHART.

The temperature instrument using thermal gradient energy harvesting is fitted to a steam pipe where the temperature difference from ambient to that of the steam pipe is used to power the instrument. A battery is included for situations where there is no steam flowing. Normally, the battery should never require replacement until its 20 year shelf life expires.

Obtaining real-time information on plant performance

In any industrial process, having quick access to real-time plant data can have a significant impact not only on performance but also other critical areas, including safety.

The challenges of a non-integrated control system

Problems arise where process data is presented in multiple formats on multiple platforms (automation, electrical and telecoms). Lack of integration in a control system can mean that operators may have no way of pinpointing issues or quickly drilling down into process data or maintenance records, for example. This can have a significant impact on process performance and operator efficiency and can cause delays in responding to emergency situations.

The solution is ABB's System 800xA distributed control system

ABB's System 800xA is a scalable extended automation system for control and monitoring, instrumentation, electrical integration, safety and maintenance for process industries.

Capable of being integrated with ABB and third party equipment, System 800xA provides operators with a single, consistent environment for managing their complete process. At the heart of System 800xA is ABB's 'Aspect Object' technology. This relates all plant data identified as Aspects, to specific plant assets, referred to as Objects. Operators can click on any of the plant assets to access real-time data for monitoring or controlling the plant independent of the type of automation or electrical device providing the control function.

In common with real-life installations worldwide, the System 800xA in the ABB control room at Imperial College enables students to control all aspects of plant operation, including data monitoring and collection, engineering configuration, maintenance and safety routines such as emergency shutdowns.

Designed with education in mind

Putting the practice behind the theory

Teaching multiple flow techniques

The pilot plant uses many different flow technologies to demonstrate the various options for industrial applications.

The challenge of flowmeter selection

Engineers are faced with a wide choice of flow technologies, each offering distinct advantages and drawbacks. As every type of liquid or gas behaves differently as it flows through a pipeline, it is important to choose the flow technology that can guarantee the best accuracy.

The solution – flowmeters in series

Imperial's pilot plant features three points where different flowmeters are installed in series.

Steam flow to the pilot plant is measured by both an ABB OriMaster M flowmeter and an ABB Swirl meter. The OriMaster M is a differential pressure flowmeter, which measures directly in mass or corrected volume units. It incorporates all of the major components needed for an orifice plate installation into a single assembly, significantly reducing installation costs.

The Swirl meter measures the flow rate based on the frequency of pressure variations formed as steam, gas or fluids meet a fixed spiral obstruction inside the meter body. In comparison to the OriMaster, the Swirl meter requires little straight pipe upstream to get the best accuracy, making it ideal for compact installations.

On the amine chemical feed line to the regenerator column, two ABB meters are used to compare electromagnetic flow measurement against the swirl measurement technique.

On the nitrogen gas line the plant utilises a Vortex flowmeter in series with a thermal mass flowmeter. Another example of two totally different technologies operating on the same process media.

Comparing communications protocols

To enable the process to be managed from the control room, all equipment on the pilot plant is linked via various forms of communication to the System 800xA control system. The Imperial College installation features examples of all of the leading types of plant-wide communications technologies, enabling students to compare and evaluate each one in an actual operational setting.

The challenges of plant-wide communications

Disagreement over a common standard has meant there are many different fieldbus protocols for use in industrial applications. With each type of fieldbus offering its own merits, it is important to be able to understand what needs to be considered when making a choice and the factors that can affect operation. These factors can include data propagation time, suitability for use in hazardous areas, power requirements and ability to integrate with other systems.

The solution - teaching multiple protocols

In a real-life application, the choice of communications protocol is likely to depend on a variety of factors, including the age of the plant and the required speed of response between the device and the control system.

In contrast to real-life industrial sites, which are likely to standardise on just one protocol, the Imperial College pilot plant utilises a combination of Profibus PA, Profibus DP, Foundation Fieldbus (HSE and H1), HART, Ethernet and WirelessHART technologies.

The plant that adapts to changing conditions

Teaching practical skills

Controlling the carbon separation process

Imperial's pilot plant will be used to run hundreds of different scenarios and experiments in coming years, calling for a highly adaptive set-up which can be readily adjusted to produce the conditions needed. This adaptability is well met by ABB's System 800xA integrated automation solution.

The challenge of maximising carbon separation efficiency

The pilot plant uses a chemical solvent of Mono-Ethanol Amine (MEA) chemical to first absorb and then assist in the separating out of the Carbon Dioxide (CO₂). For maximum process efficiency, the absorber and regenerator towers have to be maintained at steady temperatures of 45°C ±2°C and 115°C ±2°C respectively. The flow rate of the MEA to the absorber tower also needs to be carefully controlled in order to control the rate of CO₂ absorption.

The solution - integrated process control

With all plant equipment being connected to the System 800xA control system, operators are able to easily adjust device settings to experiment with different scenarios. This can be achieved simply by clicking on the icons representing those devices. Adjusting the desired set-point value on the process steam supply, for example, will enable the operator to either increase or decrease the process temperature, which can affect the ability of the MEA to absorb CO₂ via the relevant control valve.

Similarly, the plant operator can vary the feed rate of the MEA by changing the set-point of the flow control loop that utilises variable-speed drives on the MEA feed line. In this way students can appreciate the different technologies used in flow control. The increase or reduction in the flow rate will be detected by the flowmeters on the line, with the data being relayed to the System 800xA to help control the variable-speed drives.

Alarms and event management for a safe future

Subject to the same stringent safety requirements as any real-life industrial process, the Imperial College pilot plant features a comprehensive range of safety measures designed to immediately alert operators to out-of-range or emergency situations.

The challenges of handling emergency situations

Even in a fully automated control room, a human presence is still needed to ensure that emergency situations are handled quickly and efficiently. This can often be difficult in traditional control room situations, where messages may be relayed to separate systems and displayed in different formats. This can cause a delay in tracing the root of a problem, during which time the potential consequences may escalate.

The solution - integrated alarm management

The TÜV-safety certified System 800xA at Imperial College has specific alarms included for:

- Asphyxiation caused by leaking CO₂ or nitrogen gases
- Dangerously high or low levels in the stripper and scrubber columns
- Excessive pressures in the columns
- Overheating of heaters, coolers and the stripper and scrubber columns

To help operators to quickly address a problem, the System 800xA includes visual and audio alarms, CCTV cameras that focus on problem areas via the EOW and facilities to raise and lower the desk to enable the operator to handle a situation whilst standing or sitting. Automatic shutdown routines are triggered in the event of a safety alarm not being acted upon. All major events within the plant are recorded, producing historical data that can be examined to trace the conditions leading up to the alarm situation. In this way students can work to, and understand, the latest international best practice.

Did you know? The ABB equipment supplied is backed up by a 10 year agreement to provide lifecycle services and support for the installation.

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